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Sargassum muticum in eulittoral rockpools

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

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2016-03-30

A report from:

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

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This review can be cited as:

Tillin, H.M. & Budd, G., 2016. [*Sargassum muticum*] in eulittoral rockpools. 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.

DOI <https://dx.doi.org/10.17031/marlinhab.309.1>

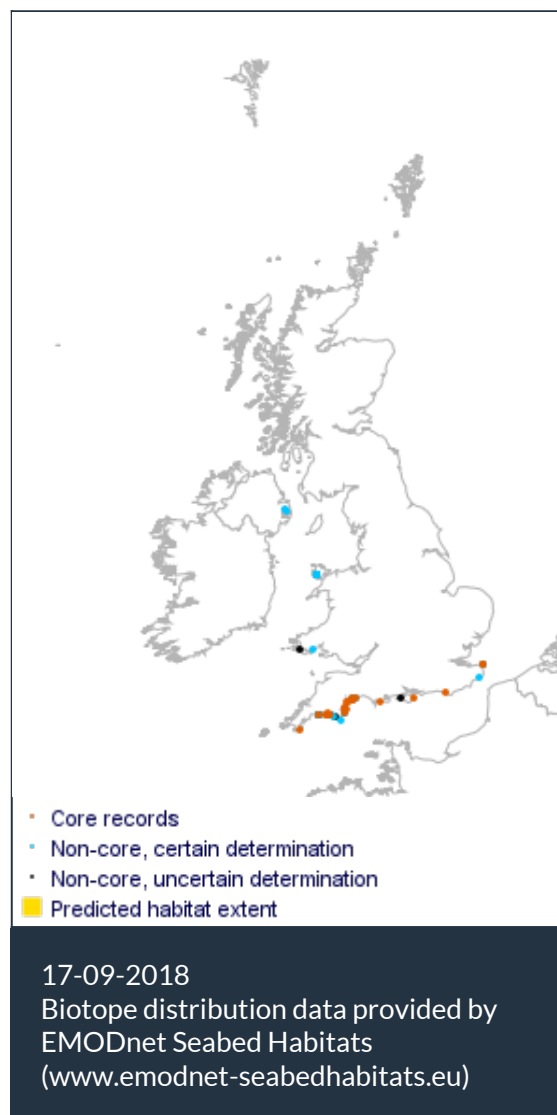


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Sargassum muticum in eulittoral rockpools.
 Photographer: Anon.
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Researched by Dr Heidi Tillin & Georgina Budd Refereed by Admin

Summary

☰ UK and Ireland classification

EUNIS 2008	A1.4121	<i>Sargassum muticum</i> in eulittoral rockpools
JNCC 2015	LR.FLR.Rkp.FK.Sar	<i>Sargassum muticum</i> in eulittoral rockpools
JNCC 2004	LR.FLR.Rkp.FK.Sar	<i>Sargassum muticum</i> in eulittoral rockpools
1997 Biotope	LR._Rkp.FK.Sar	<i>Sargassum muticum</i> in eulittoral rockpools

🔍 Description

Shallow rockpools throughout the eulittoral zone on exposed to moderately exposed shores dominated by the brown seaweed *Sargassum muticum* and the red seaweed *Corallina officinalis*. Other brown seaweeds, including the kelp *Saccharina latissima*, *Laminaria digitata* and the wrack *Fucus serratus* may occur along with *Dictyota dichotoma*, but *S. muticum* always dominates. Underneath the canopy is a rich red seaweed community which includes both foliose and filamentous species such as *Palmaria palmata*, *Chondrus crispus*, *Lomentaria articulata*, *Osmundea*

pinnatifida, *Ceramium* spp. and *Dumontia contorta*. Encrusting coralline algae and *Hildenbrandia rubra* often cover the rock surface. The foliose green seaweed *Ulva lactuca* is usually present in high abundance growing on the mobile gravel and boulders on the bottom of the rockpools, often along with other ephemeral green seaweeds such as *Cladophora rupestris* and *Ulva intestinalis*. The winkle *Littorina littorea*, the limpet *Patella vulgata* and the top shells *Gibbula cineraria* and *Gibbula umbilicalis* can often be found grazing on the biofilm of the rock surface or the seaweeds. Crevices and fissures in the rock provide cover for anemones such as *Actinia equina* and *Anemonia viridis*, cover while the prawn *Palaemon serratus* often can be found in large numbers hiding underneath the seaweed canopy or along the boulders on the bottom. Some sand scour can affect these rockpools (JNCC, 2015).

↓ Depth range

Mid shore, Lower shore

🏛️ Additional information

-

✓ Listed By

- none -

🔗 Further information sources

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Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The biotope description and information on characterizing species are taken from Connor *et al.* (2004). The biotope is characterized as shallow rockpools throughout the eulittoral zone on exposed to moderately exposed shores dominated by the brown seaweed *Sargassum muticum* and the red seaweed *Corallina officinalis*. *Sargassum muticum* and the turfs of *Corallina officinalis* are considered the key characterizing and structuring species within the biotope and the sensitivity assessments focus on these species.

Other brown seaweeds, including the kelp *Saccharina latissima*, *Laminaria digitata* and the wrack *Fucus serratus* may occur along with *Dictyota dichotoma*. Underneath the canopy is a rich red seaweed community which includes both foliose and filamentous species such as *Palmaria palmata*, *Chondrus crispus*, *Lomentaria articulata*, *Osmundea pinnatifida*, *Ceramium* spp. and *Dumontia contorta*. Encrusting coralline algae and *Hildenbrandia rubra* often cover the rock surface. The foliose green seaweed *Ulva lactuca* is usually present in high abundance growing on the mobile gravel and boulders on the bottom of the rockpools, often along with other ephemeral green seaweeds such as *Cladophora rupestris* and *Ulva intestinalis*. The sensitivity assessments describe the sensitivity of the associated macroalgae in general terms.

The winkle *Littorina littorea*, the limpet *Patella vulgata* and the top shells *Gibbula cineraria* and *Gibbula umbilicalis* can often be found grazing on the biofilm of the rock surface or the seaweeds. As grazers can be key structuring species within rockpools and the intertidal they are also considered within the sensitivity assessments.

Crevices and fissures in the rock provide cover for anemones such as *Actinia equina* and *Anemonia viridis*, cover while the prawn *Palaemon serratus* often can be found in large numbers hiding underneath the seaweed canopy or along the boulders on the bottom. These common rocky shore species while contributing to species diversity and ecological function within the biotope are not considered to be key to the biotope and are therefore only generally referred to within the assessments. More information on associated species can be found in other reviews where these are considered in detail as characterizing species.

Resilience and recovery rates of habitat

Where this biotope is impacted by pressures, recolonization of the key characterizing species *Sargassum muticum* and the turf of *Corallina officinalis* will require either regrowth from surviving holdfast or basal crusts or recolonization by propagules. *Sargassum muticum* possesses life history characteristics which make it an effective colonizer and competitor and it is an invasive species across much of its range (Engelen *et al.*, 2015). The base/holdfast is perennial (Davison, 1999) and is more tolerant of high air temperatures and desiccation (Norton, 1977a) allowing the plant to survive and retain space during periods where conditions are less favourable. The high growth rate (10 cm per day), allows this species to rapidly dominate and shade other algae. The species can reproduce sexually and self-fertilize or asexually and reaches reproductive maturity annually from the first year. Detached fronds are able to continue to grow into new plants and to produce germlings which is an effective mechanism for widespread dispersal supporting colonization or recolonization over a wide area (Engelen *et al.*, 2015). In comparison, like other brown and red algae, dispersal via propagules is limited. According to Lüning (1990), the eggs of most large perennial algae are adapted for rapid sinking. In *Sargassum muticum*, eggs have a

dispersal range of as little as 3 m in the intertidal region (Critchley, 1981, Kendrick & Walker, 1995). Though this distance can increase significantly with water movement (Norton & Fetter, 1981; Deysher & Norton, 1982). *Sargassum muticum* exploits gaps within native algal cover (Davison, 1999) and then rapidly grows and outshades native algae. Space pre-emption by crustose and turf forming algae inhibits *Sargassum muticum* recruitment (Britton-Simmons; 2006; Deysher & Norton, 1982) and light pre-emption, by canopy and understory algae reduces *Sargassum muticum* survivorship (Britton-Simmons, 2006). Pressures that impact this biotope and similar biotopes within the group that remove native species will therefore support further recolonization by *Sargassum muticum*.

The key characterizing species *Corallina officinalis* may grow continuously as a basal crust until stimulated to produce fronds (Littler & Kauker 1984; Colhart & Johanssen 1973). Littler & Kauker (1984) suggest that the crustose bases were adapted to resist grazing and desiccation whereas the fronds were adapted for higher primary productivity and reproduction. The basal crusts are tougher than the upright fronds (requiring a pressure of 94 g/mm² to penetrate compared to 43 g/mm²). Regeneration of the basal crusts provides a more rapid route to recovery than recolonization. Experiments in the intertidal in southern California found that areas scraped back to crusts recovered four times more rapidly than sterilised plots where the crusts were removed (Littler & Kauker, 1994). Other red algal species present within the red algal turf, such as *Osmundea pinnatifida* and *Chondrus crispus*, also have perennial bases that spread laterally by vegetative growth. Where the bases are removed, recovery will depend on recolonization. Areas that are cleared during the reproductive period have the potential to be rapidly colonized. *Corallina officinalis* was shown to settle on artificial substances within 1 week of their placement in the intertidal in New England summer (Harlin & Lindbergh, 1977). However, settlement plates laid out in the autumn were not recolonized until the next spring. In the lower rocky intertidal in southern California dominated by *Corallina officinalis* with foliose overstorey algae present, Littler & Kauker (1984) experimentally cleared plots and followed the recovery for 12 months. Some areas were scraped allowing the basal crusts to remain whereas others were completely sterilised (removal of all material and surfaces then scorched with a blow torch to remove bases). In scraped plots up to 15% cover of *Corallina officinalis* fronds returned within 3 months after removal of fronds and all other epiflora/fauna (Littler & Kauker, 1984) while in sterilized plots (all basal crusts removed) appearance of articulated fronds occurred 6 months following clearance. At the end of the 12 month observation period *Corallina officinalis* cover had increased to approximately 18% in plots where basal crusts remained and to approximately 10% in sterilised plots. Similarly Bamber & Irving (1993) reported that new plants grew back in scraped transects within 12 months, although the resistant crustose bases were probably not removed.

Once established turfs of *Corallina* spp. can persist for a long time, surveys of rocky intertidal ledges at Hinkley point, Somerset in England have found that the patches mapped in the 1980s (Bamber & Irving, 1993) had not changed position when resurveyed 18 years later (Burdon *et al.*, 2009). It has been suggested, but not definitively demonstrated, that turf-forming algae and canopy forming algae may represent alternate stable states on temperate rocky shores and that a shift in balance to the alternate state may prevent recovery. Lubchenco (1980) for example, on shores in New England, found that the removal of *Chondrus crispus* turf allowed the establishment of *Fucus* spp. Removal of grazers and the turf allowed *Fucus* spp. to establish 100% cover, highlighting the significance of grazers in structuring the biotope. Some potential mechanisms for inhibition of canopy forming species are space pre-emption by turfs that prevent recruitment of taller algae (Perkol-Finkel & Airoidi, 2010, Kennelly 1987) due to the coverage of suitable rock surfaces and the presence of sediments within the turf (Airoidi, 2003). Clearance experiments on rocky, intertidal shores in Southern California (Sousa, 1979) found that *Ulva* species which have a

longer reproductive season could colonize cleared areas preventing the establishment of perennial red algae. However grazing by crabs removed the green algae (Sousa, 1979), again highlighting the potential importance of grazers, particularly littorinids, to the reestablishment of this biotope.

Other macroalgal species within the biotope have differing life history and reproductive strategies and differ in dispersal strategy, longevity and growth forms so that recovery rates will vary between species. The green algae (*Ulva* spp.) that can occur in high densities in this biotope are opportunistic species that are able to rapidly colonize newly created gaps across a range of substratum 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 over extended periods coupled with a pelagic dispersal phase (Smith, 1947; Amsler & Searles (1980). Recovery of the ephemeral green algae associated with this biotope is therefore assessed as 'High' for any level of impact (where suitable habitat remains). The red algae have lower dispersal rates (Norton, 1992) but can out-compete ephemeral green algae for space through perennial holdfasts, e.g. *Palmaria palmata* or by possessing crustose bases that spread laterally over the substratum from which the fronds can regrow, e.g. *Chondrus crispus*, *Corallina officinalis*, *Osmundea pinnatifida*. Removal of the bases will inhibit recovery of some slow growing red algae and may lead to changes in composition of the understorey red algae, favouring rapid colonizers such as *Palmaria palmata* (Connor *et al.*, 2004) over species with low recruitment success such as *Osmundea pinnatifida* (Prathey, 2001). In kelp canopy removal experiments in the Isle of Man, Hawkins & Harkin (1985) observed a rapid increase in the number of *Palmaria palmata* sporelings and the species came to dominate cleared plots within five months. Recolonization from distant populations would probably take longer, however, because dispersal distances are limited, with spores sinking and attaching close to adult plants.

The kelp species within this biotope are likely to recover within two years from removal. *Saccharina latissima* (formerly *Laminaria saccharina*) is an opportunistic species with relatively fast growth rates and can reach maturity in 15-20 months (Sjøtun, 1993) and has a life expectancy of 2-4 years (Parke, 1948). Kain (1975) cleared sublittoral blocks of *Laminaria hyperborea* at different times of the year for several years. The first colonizers and succession community differed between blocks and at what time of year the blocks were cleared. *Saccharina latissima* was an early colonizer, however within 2 years of clearance the blocks were dominated by *Laminaria hyperborea*. Evidence from Engelen *et al.* (2011) indicated that complete recovery of *Laminaria digitata* and its associated epibiota occurs 18-24 month after complete removal of *Laminaria digitata*. Smith (1985) also suggested 24 months for the recovery of a *Laminaria digitata* bed.

Adult limpets and *Littorina saxatilis* may recolonize from surrounding patches of habitat where these are present. The 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 algal canopies and turfs inhibiting 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. Their presence in large numbers would hinder recovery of this biotope and may alter biotope classification to the very similar LR.FLR.Rkp.Cor.Cor biotope which occurs in similar conditions but is characterized by higher levels of grazing pressure which mean the biotope is characterized only by more resistant *Corallina officinalis* turfs and encrusting corallines.

Resilience assessment. Once established in an area, recovery of *Sargassum muticum* from impacts

will occur via regrowth from the perennial holdfast (where this survives), or recolonization of gaps by propagules from either adjacent adults or fragments of reproductive adults. Based on the high dispersal rates (via fragments of adult plants) and exploitation of gaps, resilience is assessed as 'High'. *Saccharina latissima* has also been shown to be an early colonizer within algal succession, appearing within 2 weeks of clearance. Resilience of these species has therefore been assessed as 'High' for all levels of resistance. *Ulva* spp. within the biotope are also expected to recover rapidly from any level of impact.

No direct evidence was found for age of individual *Corallina* crusts, longevity of turfs or the time to recover from basal crusts or sterilised plots to a full dense cover. New crustose bases may recruit and develop quickly but the formation of new fronds from these bases and recovery of original cover may take longer. The clearance experiments by Littler & Kauker (1984) suggest that recovery of a dense turf cover whether basal crusts remained or were totally removed would require more than 2 years. Presumably, as crusts can grow in all directions percentage cover is not a linear function and that gap closure would speed up with greater cover. Other red algal species such as *Chondrus crispus* and *Osmundea pinnatifida* and the encrusting corallines are likely to recover within two years in a mixed turf if the bases remain. Opportunistic species such as *Palmaria palmata* are likely to also recover rapidly. Recruitment of associated species of red algae is probably equally rapid, and once the algal turf has developed most of the epiphytic invertebrates would colonize quickly, although some species e.g. small brooding gastropods would take longer. The ephemeral green algae associated with the biotope are opportunist colonizers of gaps and would be expected to recover within a year. Resilience of the biotope is assessed as 'High' where resistance is 'High' (no significant impact) or 'Medium' (where <25 % of *Sargassum muticum* and *Corallina officinalis* fronds and red algae are removed and bases remain) based on regrowth from the basal crusts and vegetative growth from surrounding turfs. Where resistance is 'Low' or 'None' then resilience of *Sargassum muticum* is assessed as 'High' based on recolonization and regrowth from remaining plants and fragments but the resilience of the biotope overall is assessed as 'Medium'. Where perturbations have a large spatial footprint with widespread removal of bases over a large area then the development of an alternate state emerging with dominance by canopy forming algae is a possibility, e.g. the biotope LR.FLR.Rkp.FK. In such an instance recovery could take much longer and depend on active management or further perturbations. No evidence was found however to determine when such shifts might occur.

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 recognizable 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

Species found in the intertidal 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, although the timing of site-specific factors such as low tides will influence local acclimation. For intertidal species increased temperatures may also result in desiccation when exposed (see changes in emergence pressure). The key characterizing species and many of the associated species occur in areas which experience warmer temperatures than the UK and may therefore be adapted to a wider temperature range; acclimation by local populations to the prevailing conditions may alter sensitivity and caution should be used when basing assessments on distribution alone.

Sargassum muticum experiences warmer waters than the UK over parts of its geographic range and the temperature range in which *Sargassum muticum* may grow is between 3°C and 30°C (Norton, 1977; Hales & Fletcher, 1989). In its native Japan, *Sargassum muticum* experiences an annual temperature range of between 5°C and 28°C. In southern California, it survives in shallow lagoons and tidal pools that reach temperatures of 30°C and rarely fall below 14°C (Norton, 1977). In Alaska, *Sargassum muticum* occurs where temperatures range between 3°C and 10°C (Hales & Fletcher, 1989).

Strong (2003) found that stands of *Sargassum muticum* in Strangford Lough caused strong temperature stratification, including significant cooling of the water just above the sediment, while a thin layer at the surface canopy experienced elevated temperatures 11°C above ambient due to heat absorption of the canopy. Strong (2003) proposed that warmer water temperatures could increase gamete production and extend the reproductive period.

The key characterizing species, *Corallina officinalis* also has a cosmopolitan distribution (Guiry & Guiry, 2015) and throughout its range experiences wide variation in temperatures (although local populations may be acclimated to the prevailing thermal regime). Littler & Kauker (1984) suggested that the crustose bases of *Corallina officinalis* are more resistant of desiccation or heating than fronds. Severe damage was noted in *Corallina officinalis* fronds as a result of desiccation during unusually hot and sunny weather in summer 1983. An abrupt increase in temperature of 10 °C caused by the hot, dry 'Santa Anna' winds (between January and February) in Santa Cruz, California resulted in die back of several species of algae exposed at low tide (Seapy & Littler, 1982). Lüning (1990) reported that *Corallina officinalis* from Helgoland survived one week exposure to temperatures between 0 °C and 28 °C. Latham (2008) investigated the effects of temperature stress on *Corallina officinalis* through laboratory tests on samples collected in the Autumn in Devon, England from rockpools. Samples were kept at 15 °C for three days and then exposed to temperatures of 5 °C, 15 °C, 20 °C, 25 °C and 30 °C (the normal range of temperature experienced was suggested to be between 5 and 15 °C). At 35 °C the *Corallina* was completely bleached after 3 days with a sample kept at 30 °C beginning to bleach. After 7 days (the end of the experiment) the sample kept at 30 °C was partially bleached. Samples kept at 5, 15, 20 and 25 °C showed little change in chemicals produced in reaction to thermal stress and no bleaching suggesting the temperatures in that range had not induced stress reactions. Littler & Kauker, (1984) suggest that the basal crustose stage of *Corallina officinalis* is an adaptation to resist sand scour and wave shearing as well as physiological stressors such as desiccation and heating. *Osmundea pinnatifida* also regrows annually from the base following summer die-back

In an exceptionally hot summer (1983, with an increase of between 4.8 and 8.5 °C), Hawkins & Hartnoll (1985) observed no temperature bleaching of adult *Himantalia elongata* (although some buttons were bleached) or other canopy forming species. However, understorey red algae showed more signs of damage with bleached *Corallina officinalis* and 'lithothamnia' observed around the edges of pools due to dessication. Occasional damaged specimens of *Palmaria palmata*, *Osmundea pinnatifida* and *Mastocarpus stellatus* were observed.

Tolerance of increased temperatures varies between the associated red algal species. *Chondrus crispus* has a wide distribution it is found extensively throughout Europe and North America records also recorded under a number of synonyms from Africa and Asia (Guiry & Guiry, 2015). In New Hampshire, USA, *Chondrus crispus* grows abundantly in waters with an annual variation in surface temperature from -1 to +19°C (Mathieson & Burns, 1975). The species is therefore unlikely to be particularly intolerant of temperature changes in British and Irish waters (Holt *et al.*, 1995). The optimum temperature for growth has been reported as 10-15°C (Fortes & Lüning, 1980), 15°C (Bird *et al.*, 1979), 15-17°C (Tasende & Fraga, 1999) and 20°C (Simpson & Shacklock, 1979). Above the optimum temperature, growth rate is reported to decline (Bird *et al.*, 1979; Simpson & Shacklock, 1979). *Chondrus crispus* plants acclimated to growth at 20°C (vs. 5°C) had higher levels of chlorophyll a and phycobilins, resulting in higher rates of light limited photosynthesis for a given photon flux density (Kuebler & Davison, 1995). Plants grown at 20°C were able to maintain constant rates of light saturated photosynthesis at 30°C for 9 hours. In contrast, in plants acclimated to 5°C, light saturated photosynthetic rates declined rapidly following exposure to 30°C (Kuebler & Davison, 1993). Prince & Kingsbury (1973) reported cessation of growth in *Chondrus crispus* cultures at 26°C, first mortality of spores at 21.1°C and total mortality of spores at 35-40°C, even if exposed for just 1 minute. *Palmaria palmata* does well in low temperatures, with an optimum between 6 and 15°C, consistent with a distribution in northern temperate and arctic waters. This species is also found in warmer temperate waters as far south as Portugal in Europe and with localized large populations in northern Spain (Garbary *et al.*, 2012 and references therein). In the laboratory, plants only became fertile if left at temperatures between 5-7°C with a short light period (Van der Meer, 1979). Temperatures at or above 15°C may induce physiological stress (Werner & Dring, 2011; Morgan *et al.*, 1980). The fronds of *Osmundea pinnatifida* undergo annual die-back in the summer (Prathep, 2001) while the crustose holdfasts remain suggesting that the bases are more resistant.

Most of the other species within the biotope are distributed to the north and south of Britain and Ireland and unlikely to be adversely affected by a chronic temperature increase at the pressure benchmark.

Saccharina lattissima is widely distributed in the north Atlantic from Svalbard to Portugal (Birkett *et al.*, 1998; Connor *et al.*, 2004; Bekby & Moy 2011; Moy & Christie 2012). *Saccharina latissima* is therefore relatively close to the southern edge of its range in the South of England and may be vulnerable to long-term increases in temperature. The thermal optimum of *Laminaria digitata* is between 10-15°C, with reproductive ability impaired to 20% at 18°C (Arzel, 1998). Spore production only occurs between 5-10°C and is the most temperature sensitive stage of reproduction in *Laminaria digitata*. A minimum of 10 weeks a year between 5-18°C is needed in order to ensure spore formation and hence reproduction (Bartsch *et al.*, 2013). Outside this temperature range, reproduction is severely reduced and the species is at risk from local extinction in the long-term and replacement by *Laminaria ochroleuca*, a species with a more southern distribution. In addition, a temperature increase to 22-23°C causes cell damage and death (Sundene, 1964; Bolton & Lüning, 1982).

The distribution of *Lithophyllum incrustans* and other crusting corallines in southern Europe and the Mediterranean suggest that these are tolerant of higher temperatures and within pools, rather than open rock, will be protected from desiccation. *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).

Limpets, *Patella vulgata* and littorinids also occur within 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* 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).

Sensitivity assessment. Based on the global distribution of *Sargassum muticum* and *Corallina officinalis* and the experiments by Latham (2008), which approximate to the pressure benchmark more than the observations of extreme events reported by Seapy & Littler, (1982) and Hawkins & Hartnoll, (1985) it is suggested that *Sargassum muticum* and *Corallina officinalis* would not be sensitive to either an acute or chronic increase in temperature at the pressure benchmark. Where bases and holdfasts survive any increases in temperature above the pressure benchmark they would provide a mechanism for biotope recovery. The biotope assessment is based on the key characterizing *Sargassum muticum*, *Corallina* turf and encrusting corallines but it should be noted that many of the associated species are considered to have 'High' resistance to changes in temperature at the pressure benchmark. Biotope resistance is assessed as 'High' and resilience as 'High' and the biotope is considered to be 'Not sensitive'. It should be noted that 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* 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.

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 (Davenport & Davenport, 2005).

The temperature range in which *Sargassum muticum* may grow is between 3°C and 30°C (Norton, 1977; Hales and Fletcher, 1989). Early life stages are more sensitive and reductions in temperature from 17°C to 7°C decrease germling growth (Steen, 2003). *Sargassum muticum* experiences colder waters than the UK over parts of its geographic range and it has successfully invaded the cold waters of southern Alaska (Hales & Fletcher, 1989) and Scandinavia (Karlsson &

Loo, 1999). It can survive short periods of freezing temperatures (Norton, 1977a), although a single hour exposed to temperatures of -9°C was lethal to the entire plant (Norton, 1977). The branches can survive at -1°C (Norton, 1977) and the holdfast and stipe can survive lower temperatures (Critchley *et al.*, 1987; Karlsson, 1988). In Sweden, early colonists observed in 1987 were noted to survive the winter, despite formation of ice on the nearby sea surface (Karlsson & Loo, 1999).

Under extremely low temperatures, components of the community demonstrate tolerance. Lüning (1990) reported that *Corallina officinalis* from Helgoland survived 0°C when exposed for one week. New Zealand specimens were found to tolerate -4°C (Frazer *et al.*, 1988). Lüning (1990) suggested that most littoral algal species were tolerant of cold and freezing. For example, the photosynthetic rate of *Chondrus crispus* recovered after 3hrs at -20°C but not after 6 hrs (Dudgeon *et al.*, 1990).

Palmaria palmata does well in low temperatures, with an optimum between 6 and 15°C , consistent with a distribution in northern temperate and arctic waters (Garbary *et al.*, 2012 and references therein). In the laboratory, plants only became fertile if left at temperatures between $5-7^{\circ}\text{C}$ with a short light period (Van der Meer, 1979). Based on distribution and requirement for lower temperatures for reproduction this species is not considered sensitive to the assessed decreases in temperature.

Ulva spp. are found in a wide temperature range and in areas which frequently experience freezing conditions and are vulnerable to ice scour (Seed & Suchanek 1992). The tolerance of *Littorina littorea* and *Littorina saxatilis* collected in the winter (and thus acclimated to lower temperatures) to low temperatures was tested in the laboratory. The median lower lethal temperature tolerance was -16.4 and -13°C respectively (Davenport & Davenport, 2005). A decrease in temperature at the pressure benchmark is therefore unlikely to negatively affect these species. Adults of *Patella vulgata* 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). However, 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). In colder conditions an active migration by mobile species may occur down the shore to a zone where exposure time to the air (and hence time in freezing temperatures) is less.

The kelp *Laminaria digitata* is thought to be a northern species and it is unlikely to be sensitive to a reduction in temperature at the benchmark level. Similarly, *Saccharina latissima* is widely distributed and occurs in more northern regions (to Svalbard) (Birkett *et al.*, 1998; Bekby & Moy, 2011; Moy & Christie, 2012) and is not considered sensitive to the assessed decreases in temperature.

Sensitivity assessment. 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)**Low**

Q: High A: Medium C: Medium

Medium

Q: High A: Low C: Medium

Medium

Q: High A: Low C: Medium

Local populations may be acclimated to the prevailing salinity regime and may therefore exhibit different tolerances to other populations subject to different salinity conditions and therefore caution should be used when inferring tolerances from populations in different regions. This biotope is found in full (30-35 ppt) salinity (Connor *et al.*, 2004). High air temperatures cause surface evaporation of water from pools, so that salinity steadily increases. The extent of temperature and salinity change is affected by the frequency and time of day at which tidal inundation occurs. If high tide occurs in early morning and evening the diurnal temperature follows that of the air, whilst high water at midday suddenly returns the temperature to that of the sea (Pyefinch, 1943). Heavy rainfall, followed by tidal inundation can cause dramatic fluctuations in salinity, and values ranging from 5-30 psu have been recorded in rockpools over a period of 24 hrs (Ranade, 1957). As a consequence of such a regime, the entire LR.FLR.Rkp community will be adapted, to a certain degree, to fluctuating salinities. It should be noted that local populations may be acclimated to the prevailing salinity regime and may therefore exhibit different tolerances to other populations subject to different salinity conditions and therefore caution should be used when inferring tolerances.

Sargassum muticum germlings from fertile plants collected from Bembridge, Isle of Wight, were tolerant, in 4 week laboratory experiments, of a wide range of salinities, 6.8 - 34‰ (Hales & Fletcher, 1989). Optimal growth occurred at a temperature of 25°C and a salinity of 34 ‰ (Hales & Fletcher, 1989). No evidence was found for tolerance of salinities above 34 ‰. Species occurring in rockpools may experience higher salinities due to evaporation on hot days, however, as *Sargassum muticum* can shade pools this may reduce evaporation and tolerance of hypersalinity is therefore not inferred from its occurrence in rockpools.

The characterizing species *Corallina officinalis* is found in rockpools (as in this assessed biotope) where salinities may fluctuate markedly during exposure to the air. Kinne (1971) cites maximal growth rates for *Corallina officinalis* between 33 and 38 psu in Texan lagoons. Edyvean & Ford (1984b) suggest that populations of the encrusting coralline *Lithophyllum incrustans* are affected by temperature changes and salinity and that temperature and salinity 'shocks' induce spawning but no information on thresholds was provided (Edyvean & Ford, 1984b). Populations of *Lithophyllum incrustans* were less stable in rockpools with a smaller volume of water that were more exposed to temperature and salinity changes due to lower buffering capacity. Sexual plants (or the spores that give rise to them) were suggested to be more susceptible than asexual plants to extremes of local environmental variables (temperature, salinity etc.) as they occur with greater frequency at sites where temperature and salinity were more stable (Edyvean & Ford, 1984b).

Available evidence demonstrates that some of the red algae present can tolerate at least short-term increases in salinity at the pressure benchmark. *Chondrus crispus* is found in a range of salinities across its range and has been reported from sites with yearly salinity range 0-10 psu and 10-35 psu (Lindgren & Åberg 1996) and sites from an average of 26-32 psu. However, at different salinities the ratio between the abundance of the tetrasporophyte phase and the gametophyte alters (Guidone & Grace, 2010). Mathieson & Burns (1971) recorded maximum photosynthesis of *Chondrus crispus* in culture at 24 psu, but rates were comparable at 8, 16 and 32 psu. Photosynthesis continued up to 60 psu. Bird *et al.* (1979) recorded growth of Canadian *Chondrus crispus* in culture between 10 and 50 psu, with a maximum at 30 psu. *Chondrus crispus* would therefore appear to be euryhaline and tolerant of a range of salinities. Laboratory experiments have defined the upper and lethal lower limits for *Palmaria palmata* as 15 psu and 50 psu, (Karsten

et al., 2003) with optimal salinity defined as 23-34 psu (Robbins, 1978).

The associated *Ulva* species can survive hypersaline conditions in supralittoral rockpools subjected to evaporation and are considered to be a very euryhaline, 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; Reed & Russell (1979). 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. No direct evidence was found to assess sensitivity to this pressure. Although some increases in salinity may be tolerated by the associated species present these are generally short-term and mitigated during tidal inundation and laboratory experiments provide information only on short-term exposure. An increase at the pressure benchmark may lead to an increase in abundance of the very euryhaline *Ulva* spp and *Palmaria palmata* and other changes in the composition of the algal turf and alter the biotope from the description. Biotope resistance is therefore assessed as 'Low' although the bases may be more resistant and survive) and recovery as 'High' (following restoration of usual salinity and based on *Sargassum muticum*). Biotope sensitivity is therefore assessed as 'Low'.

Salinity decrease (local)

Low

Q: Low A: NR C: NR

Medium

Q: High A: Low C: Medium

Medium

Q: Low A: Low C: Low

This biotope is recorded in full salinity habitats (Connor *et al.*, 2004). and a change at the pressure benchmark refers to a decrease in salinity from full to reduced (18-30 ppt). Heavy rainfall, followed by tidal inundation can cause dramatic fluctuations in salinity, and values ranging from 5-30 psu have been recorded in rockpools over a period of 24 hrs (Ranade, 1957). As a consequence of such a regime, the entire LR.FLR.Rkp community will be adapted, to a certain degree, to fluctuating salinities.

Sargassum muticum germlings from fertile plants collected from Bembridge, Isle of Wight, were tolerant of four weeks exposure to a wide range of salinities, 6.8 - 34‰, in laboratory experiments (Hales & Fletcher, 1989). Optimal growth occurred at a temperature of 25°C and a salinity of 34‰ (Hales & Fletcher, 1989). Norton (1977) found that, in culture, vegetative branches could tolerate minimum salinities down to 9 ppt but growth rates were much reduced. Transplanted mature plants (Steen, 2004) were also found to show a decrease in growth and reproductive rate at a station with salinities in the range of approximately 9.5 ppt to 17.4 ppt over a six month period. Field studies have also observed an absence of *Sargassum muticum* in shallow Alaskan waters (6 m) at a salinity of 8.64 ppt due to snow melt (Norton, 1977). Steen (2004), suggested that the invasive capabilities decrease with reduced salinity, with a complete inability to invade areas with salinities lower than 15 ppt and potentially an inability to compete with other species at salinities lower than 25 ppt.

In the Baltic, *Corallina officinalis* is confined to deeper waters as surface salinity decreases (Kinne, 1971) suggesting that full salinity is required in the long-term although short-term fluctuations may be tolerated (although the thresholds of this tolerance are not clear). Kinne (1971) cites maximal growth rates for *Corallina officinalis* between 33 and 38 psu in Texan lagoons, so that a decrease in salinity at the pressure benchmark would be predicted to lead to reduced growth.

The red algae *Chondrus crispus* does occur in areas of 'low' salinity, it is found in estuaries in New

Hampshire, USA, where surface water salinity varies from 16-32 psu (Mathieson & Burns, 1975). Mathieson & Burns (1971) recorded maximum photosynthesis of *Chondrus crispus* in culture at 24 psu, but rates were comparable at 8, 16 and 32 psu. Tasende & Fraga (1999) cultured *Chondrus crispus* spores from north west Spain and concluded that growth was correlated with salinity between 23 and 33 psu. A reduction in salinity, therefore, is unlikely to result in mortality of *Chondrus crispus* but may suppress growth, particularly at the lower end of the benchmark (18 ppt). Other red algae associated with the biotope may be more sensitive. Laboratory experiments have defined the upper and lethal lower limits for *Palmaria palmata* as 15 psu and 50 psu, (Karsten *et al.*, 2003) with optimal salinity defined as 23-34 psu (Robbins, 1978). In-situ *Palmaria palmata* from the Arctic Kongsfjord (Spitsbergen) exposed for four days to salinities of 15 psu following freshwater run-off suffered high levels of mortality (Karsten *et al.*, 2003).

Based on their occurrence in estuaries, it is clear that some of the species associated with this biotope (*Ulva* spp. and littorinids) have a high tolerance for this pressure. However, it should be noted that local populations may be acclimated to the prevailing salinity regime and may therefore exhibit different tolerances to other populations subject to different salinity conditions so that caution should be used when inferring tolerances from populations in different regions. *Ulva* species are considered to be a very euryhaline species, tolerant of extreme salinities ranging from 0 psu to 136 psu (Reed & Russell, 1979). although some variation in salinity tolerance between populations of *Ulva intestinalis* have been found indicating that plants have some adaptation to the local salinity regime (Reed & Russell, 1979). *Littorina littorea* is found in waters of full, variable and reduced salinities (Connor *et al.*, 2004) and so populations are considered tolerant of decreases in salinity at the pressure benchmark.

Sensitivity assessment. Although some daily changes in salinity may be experienced these will be mitigated during tidal inundation. This biotope is considered, based on *Sargassum muticum* (Hale & Fletcher, 1989, Norton, 1977) and *Corallina officinalis* distribution and the evidence from Kinne (1971), to be sensitive to a decrease in salinity at the pressure benchmark. The sensitivity of *Palmaria palmata* appears to be greater than some other turf-forming species such as *Chondrus crispus*. A change in salinity at the pressure benchmark is considered to lead to some mortality of the key characterizing species and potentially *Palmaria palmata* although the tolerance threshold reported in laboratory studies is slightly lower than the assessed benchmark. Replacement by more resistant species such as *Chondrus crispus* may occur. Biotope resistance is therefore assessed as 'Low' although the bases may be more resistant and survive) and recovery as 'High' (following restoration of usual salinity and based on *Sargassum muticum*). Biotope sensitivity is therefore assessed as 'Low'.

Water flow (tidal current) changes (local)

High

Q: High A: High C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: High C: High

No evidence to assess this pressure was found. The rock pool habitat will provide some protection from water flows although surface topography may create some turbulence disrupting currents. The fronds of the algae will reduce flow through friction and reduce drag and the risk of breakage and dislodgement. Boller and Carrington (2006), for example, found that the canopy created by the turf of *Chondrus crispus* reduced drag forces on individual plants by 15-65%. The coralline crusts characterizing this biotope are securely attached and as these are flat are subject to little or no drag. As biotopes dominated by turfs of *Corallina officinalis* (and containing similar associated species) are found in a range of flow rates from 'moderately strong' (0.5-1.5 m/s) to very weak, negligible flows) (Connor *et al.*, 2004; Dommasnes, 1969), this key characterizing and

structuring species and the associated red and green algae and limpets and littorinids are considered unlikely to be sensitive to changes at the pressure benchmark. Moderate water movement is beneficial to seaweeds as it carries a supply of nutrients and gases to the plants and removes waste products. However, if flow becomes too strong, plants may become displaced. Additionally, an increase to stronger flows may inhibit settlement of spores and remove adults or germlings. However, *Corallina officinalis* have a compact, turf forming growth which reduce water flow through turbulence and friction and are probably resistant to displacement by an increase in water flow.

Sensitivity assessment. An increase in water flow may inhibit settlement of spores and remove adults or germlings. However the brown and red algae have a compact, turf forming growth which reduce water flow through turbulence and friction and are probably resistant to displacement by an increase in water flow at the pressure benchmark. Decreased water flow may enhance sediment settlement in the turf and may result in less spores being removed. There is no evidence to suggest that either of these effects would negatively impact the biotope. Biotope resistance to increased and decreased water flow (at the pressure benchmark) is assessed as 'High' and resilience as 'High (by default)' so that the biotope is assessed as 'Not sensitive'. This biotope is considered to have 'High' resistance and 'High' resilience to this pressure at the benchmark and is therefore assessed as 'Not sensitive'.

Emergence regime changes

Medium

Q: High A: Medium C: High

High

Q: High A: High C: High

Low

Q: High A: Medium C: High

The emergence regime over the tidal cycle is an important factor structuring this, and other, intertidal biotopes. An increase in emergence may lead to shallow pools drying out, greater exposure to air temperatures with corresponding fluctuations in water temperature and changes in salinity following evaporation or dilution by rainfall. Mobile species within this biotope could relocate to preferred shore heights but an increase or decrease in abundance of predators and grazers may alter the structure of the assemblage. Connor *et al.*, (2004) report that this biotope occurs throughout the eulittoral zone and therefore it is likely to have some tolerance for increased or decreased emergence.

Sargassum muticum is found on the lower shore and sublittoral and in rockpools. Although rockpools allow *Sargassum muticum* to occur further up the shore, individuals in rock pools are usually smaller and may have lower reproductive rates (plants are often small and reproduction may be impaired (Fletcher & Fletcher 1975). Fronds exposed to air in hot sunshine can die within an hour and three hours exposure can kill fronds in the shade (Norton, 1977). An increase in emergence may therefore expose *Sargassum muticum* to unfavourable conditions resulting in reduced growth or mortality. The holdfast can survive and is more resistant to desiccation, so that recovery may be rapid from short-term desiccation events.

The associated ephemeral green algae, *Patella vulgata* and littorinids are found at a range of shore levels and are found in abundance at higher shore levels than this biotope typically occurs at. These species are therefore considered not to be affected by increased emergence. Experimental grazer removal has allowed algae including *Palmaria palmata*, *Ceramium* sp. and *Osmundea* (as *Laurencia*) *pinnatifida* to grow higher on the shore (during winter and damp summers) than usual suggesting that grazing also limits the upper shore extent of this biotope. *Palmaria palmata* grew more abundantly higher up the shore following the massive mortality of molluscan grazers after the *Torrey Canyon* oil spill (Hawkins & Hartnoll, 1983).

Sargassum muticum, *Corallina officinalis* and many of the associated species are found subtidally. Decreased emergence is likely to lead to the habitat the biotope is found in becoming more suitable for the lower shore species generally found below the biotope, leading to replacement by, for example, a kelp dominated biotope with red algae and *Corallina officinalis* surviving under the canopy.

Sensitivity assessment. A decrease in emergence would mean that shallow rock pools would be at less risk of desiccation. In addition, depending on the nature of the surrounding bedrock, the rockpool may become slightly deeper. As a result, it is possible that species diversity could increase but, on the whole biotopes occurring in the mid-shore are likely to be tolerant of some decrease in emergence at the benchmark level. Resistance is therefore assessed as 'High' and resilience as 'High' and the biotope (particularly where it occurs on the mid-shore) is considered to be 'Not sensitive' to decreased emergence. *Sargassum muticum* and some algae species within the biotope are sensitive to desiccation and high light levels and increased emergence may reduce growth rates and therefore biomass and result in some changes in species composition. Biotope resistance is assessed as 'Medium' and resilience is assessed as 'High': biotope sensitivity to increased emergence is therefore assessed as 'Low'.

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 recorded from locations that are judged to range from moderately exposed, exposed or sheltered (Connor *et al.*, 2004), while Dommasnes, (1969) recorded *Corallina officinalis* turfs from very wave sheltered areas in Norway. The degree of wave exposure influences wave height, as in more exposed areas with a longer fetch waves would be predicted to be higher. As this biotope occurs across a range of exposures, this was therefore 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.

The structure of kelps enables them to survive a range of wave conditions from exposed to sheltered conditions (Connor *et al.*, 2004, Harder *et al.*, 2006). Physiological differences between kelps are evident between low wave exposure and medium-high wave exposure. The greatest wet weight of *Laminaria digitata* occurs at low wave exposure (mean significant wave height <0.4 m) decreasing by a mean of 83% in medium to high wave exposures (mean significant wave height >0.4m; Gorman *et al.*, 2013).

The associated species *Palmaria palmata* can be abundant on moderately exposed and sheltered shores (Irvine & Guiry, 1983), suggesting that over its range it experiences wide variation in significant wave height and is therefore tolerant of both increases and decreases at the pressure benchmark. A decrease in wave exposure at the pressure benchmark is unlikely to affect *Palmaria palmata* directly. Decreases greater than the pressure benchmark that lead to changes in suspended solids and subsequent deposition may lead to changes in the assemblage (see siltation and changes in suspended sediment pressures).

Sensitivity assessment. The biotope is found across a range of wave exposures, mid-range populations are considered to have 'High' resistance to a change in significant wave height at the pressure benchmark. Resilience is assessed as 'High', by default, and the biotope is considered '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 at levels greater than the pressure benchmark may adversely impact the biotope. No information was found concerning the effects of heavy metals on turf forming and encrusting coralline algae. Bryan (1984) suggested that the general order for heavy metal toxicity in seaweeds is: organic Hg > inorganic Hg > Cu > Ag > Zn > Cd > Pb. Contamination at levels greater than the pressure benchmark may adversely impact the biotope. Little information was found concerning the intolerance of *Chondrus crispus* to heavy metals. Burdin & Bird (1994) reported that both gametophyte and tetrasporophyte forms accumulated Cu, Cd, Ni, Zn, Mn and Pb when immersed in 0.5 mg/l solutions for 24 hours. No effects were reported however, and no relationship was detected between hydrocolloid characteristics and heavy metal accumulation. Cole *et al.* (1999) reported that Hg was very toxic to macrophytes. The sub-lethal effects of Hg (organic and inorganic) on the sporelings of an intertidal red algae, *Plumaria elegans*, were reported by Boney (1971). 100% growth inhibition was caused by 1 ppm Hg.

Most of the information available suggests that adult gastropod molluscs are rather tolerant of heavy-metal toxicity (Bryan, 1984). Winkles may absorb metals from the surrounding water by absorption across the gills or from their diet, and evidence from experimental studies on *Littorina littorea* suggest that diet is the most important source (Bryan *et al.*, 1983). The species has been suggested as a suitable bioindicator species for some heavy metals in the marine environment. Bryan *et al.* (1983) suggested that the species is a reasonable indicator for Ag, Cd, Pb and perhaps As. In the Fal estuary *Patella vulgata* occurs at, or just outside, Restronguet Point, at the end of the creek where metal concentrations are in the order: Zinc (Zn) 100-2000 µg/l, copper (Cu) 10-100µg/l and cadmium (Cd) 0.25-5µg/l (Bryan & Gibbs, 1983). However, in the laboratory *Patella vulgata* was found to be intolerant of small changes in environmental concentrations of Cd and Zn by Davies (1992). At concentrations of 10µg/l pedal mucus production and levels of activity were both reduced, indicating a physiological response to metal concentrations. Exposure to Cu at a concentration of 100 µg/l for one week resulted in progressive brachycardia (slowing of the heart beat) and the death of limpets. Zn at a concentration of 5500 µg/l produced the same effect (Marchan *et al.*, 1999).

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

However contamination at levels that exceed the benchmark may lead to greater impacts. Where exposed to direct contact with fresh hydrocarbons, encrusting coralline algae appear to have a high intolerance. Crump *et al.* (1999) described "dramatic and extensive bleaching" of '*Lithothamnium*' following the *Sea Empress* oil spill. Observations following the *Don Marika* oil spill (K. Hiscock, pers. comm.) were of rockpools with completely bleached coralline algae. However, Chamberlain (1996) observed that although *Lithophyllum incrustans* was affected in a short period of time by oil during the *Sea Empress* spill, recovery occurred within about a year. The oil was found

to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area.

Following the *Torrey Canyon* oil spill in 1967, oil and detergent dispersants affected high shore specimens of *Corallina officinalis* more than low shore specimens. Plants in deep pools were afforded some initial protection, although probably later affected by contaminated runoff. In areas of heavy spraying, however, *Corallina officinalis* was killed (Smith 1968). Intolerance to hydrocarbon pollution has been assessed to be high, as key structural and important characterizing coralline algal species will be lost and the biotope not be recognized in their absence.

The long-term effects on *Chondrus crispus* of continuous doses of the water accommodated fraction (WAF) of diesel oil were determined in experimental mesocosms (Bokn *et al.*, 1993). Mean hydrocarbon concentrations tested were 30.1 µg/l and 129.4 µg/l. After 2 years, there were no demonstrable differences in the abundance patterns of *Chondrus crispus*. Kaas (1980, cited in Holt *et al.*, 1995) reported that the reproduction of adult *Chondrus crispus* plants on the French coast was normal following the *Amoco Cadiz* oil spill. However, it was suggested that the development of young stages to adult plants was slow, with biomass still reduced 2 years after the event. O'Brien & Dixon (1976) and Grandy (1984, cited in Holt *et al.*, 1995) comment on the high intolerance of red algae to oil/dispersant mixtures, but it is unclear which factor is responsible for the intolerance.

No significant effects of the *Amoco Cadiz* spill were observed for *Laminaria* populations and the *World Prodigy* spill of 922 tons of oil in Narragansett Bay had no discernible effects on *Laminaria digitata* (Peckol *et al.*, 1990). Mesocosm studies in Norwegian waters showed that chronic low level oil pollution (25 µg/L) reduced growth rates in *Laminaria digitata* but only in the second and third years of growth (Bokn, 1985). Where exposed to direct contact with fresh hydrocarbons, encrusting calcareous algae have a high intolerance. The sensitivities of the faunal components of the kelp bed are not known although amphipods normally suffer high mortality in oil affected areas. Analysis of kelp holdfast fauna after the *Sea Empress* oil spill in Milford Haven illustrated decreases in number of species, diversity and abundance at sites nearest the spill (SEEEC, 1998).

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 pressure benchmark may adversely impact the biotope. Smith (1968) reported that oil and detergent dispersants from the *Torrey Canyon* spill affected high water plants of *Corallina officinalis* more than low shore plants and some plants were protected in deep pools. In areas of heavy spraying, however, *Corallina officinalis* was killed (Smith, 1968). Regrowth of fronds had begun within two months after spraying ceased (Smith, 1968). O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil or dispersant contamination, possibly due to the susceptibility of phycoerythrins to destruction. They also reported that red algae are effective indicators of detergent damage since they undergo colour changes when exposed to relatively low concentration of detergent. However, Smith (1968) reported that red algae such as *Chondrus crispus*, *Mastocarpus stellatus* and *Laurencia pinnatifida* were amongst the algae least affected by detergents. Laboratory studies by Grandy (1984) on the effects of oil and dispersants on several red algal species concluded that they were all sensitive to oil/dispersant mixtures, with little difference between adults, sporelings, diploid or haploid life stages.

Cole *et al.* (1999) suggested that herbicides were (not surprisingly) very toxic to algae and macrophytes. Hoare & Hiscock (1974) noted that with the exception of *Phyllophora* species, all red algae including encrusting coralline forms, were excluded from the vicinity of an acidified halogenated effluent discharge in Amlwch Bay, Anglesey and that intertidal populations of *Corallina officinalis* occurred in significant amounts only 600m east of the effluent. Chamberlain (1996) observed that although *Lithophyllum incrustans* was quickly affected by oil during the *Sea Empress* spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area.

Most pesticides and herbicides were suggested to be very toxic for invertebrates, especially crustaceans (amphipods isopods, mysids, shrimp and crabs) and fish (Cole *et al.*, 1999).

Radionuclide contamination

No evidence (NEv)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

No evidence was found to assess this pressure at the benchmark. Algae bioaccumulate radionuclides (with extent depending on the radionuclide and the algae species). Adverse effects have not been reported at low levels.

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

The effects of reduced oxygenation on algae are not well studied. Plants require oxygen for respiration, but this may be provided by production of oxygen during periods of photosynthesis. Lack of oxygen may impair both respiration and photosynthesis (see review by Vidaver, 1972). 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). 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.

No evidence was found to assess this pressure for the red algae turfs. However, the associated species are unlikely to be impacted by this pressure, at the benchmark. Experiments have shown that thallus discs of *Ulva lactuca* plants can survive prolonged exposure to anoxia and hypoxia (Vermaat & Sand-Jensen, 1987; Corradi *et al.*, 2006). Following resumption of normal oxygen conditions gametes were produced. The associated invertebrate species also show high tolerances for reduced oxygen at levels that exceed the pressure benchmark. *Littorina littorea* can easily survive 3-6 days of anoxia (Storey *et al.*, 2013). Limpets can also 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. *Patella vulgata* and *Littorina littorea* are able to respire in air, mitigating the effects of this pressure during the tidal cycle.

Sensitivity assessment. No direct evidence for the effects of hypoxia on red algal turfs was found. As the biotope will only be exposed to this pressure when submerged and respiration will occur in air, biotope resistance was 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: Medium C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: Medium 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). No evidence was found to assess the sensitivity of the key characterizing species, *Sargassum muticum*. In the Mediterranean Salas *et al.* (2006) note that the presence of *Sargassum* is an indicator of good water quality but no further information was provided.

Marine algae are often nutrient limited, by nitrogen in particular, so an increase in nutrient levels usually results in increase growth and fecundity. In the Bay of Fundy, for example, where there is a tidal flux of nutrients from the marshes there is luxurious growth of *Palmaria palmata* (Morgan *et al.*, 1980). However, very high levels of nutrients can be toxic to macroalgae. Plants placed in tanks with continuous immersion in high nutrients over several weeks stopped growing (Morgan *et al.*, 1980). In general, the great majority of reports refer to an increase in the number of green algae associated with eutrophicated waters, usually at the expense of red and brown algae.

Over geological timescales periods of increased nutrient availability have experienced increases in the distribution of crustose coralline species at the expense of corals (Littler & Littler, 2013), suggesting that this group have some tolerance for enhanced nutrient levels. Overall, Littler & Littler (2013) suggest that corallines as a group can tolerate both low and elevated levels of nutrients. The key characterizing *Corallina officinalis* and the associated green algae species have been identified worldwide as species that occur in areas subject to increased nutrient input within the vicinity of sewage outfalls and at intermediately polluted sites (Bellgrove *et al.*, 2010; Littler & Murray, 1975; May, 1985; Brown *et al.*, 1990; Bellgrove *et al.*, 1997, Arevalo *et al.*, 2007). For example Kindig & Littler (1980) demonstrated that *Corallina officinalis* var. *chilensis* in South California showed equivalent or enhanced health indices, highest productivity and lowest mortalities (amongst the species examined) when exposed to primary or secondary sewage effluent. Little difference in productivity was noted in chlorinated secondary effluent or pine oil disinfectant. However, specimens from unpolluted areas were less tolerant, suggesting physiological adaptation to sewage pollution (Kindig & Littler, 1980). Grazers in the biotope may benefit from increased availability of food resources, due to enhanced growth.

Atalah & Crowe (2010) added nutrients to rockpools. The experimental treatments do not directly relate to the pressure benchmark but indicate some general trends in sensitivity. The rockpools were occupied by a range of algae including encrusting corallines, turfs of *Mastocarpus stellatus*, *Chondrus crispus* and *Corallina officinalis* and green and red filamentous algae. Nitrogen and phosphorous enhancement was via the addition of fertilisers, as either 40 g/litre or 20 g/litre. The treatments were applied for seven months and experimental conditions were maintained every two weeks. Nutrients had no significant effect on the cover of crustose coralline algae or the cover

of red turfing algae (Atalah & Crowe, 2010). However, the cover of green filamentous algae increased where grazers were removed (Atalah & Crowe, 2010). The study suggests that, although red algal turfs may be tolerant of eutrophication and may even benefit, biotope composition may alter due to the proliferation of fast growing ephemeral algae.

Laminaria digitata seems to follow the trends reported above with a growth peak occurring in conjunction with nutrient upwelling from deeper waters in Norway (Gévaert *et al.*, 2001). Macroalgal growth is generally nitrogen-limited in the summer, as illustrated by the growth rates of *Laminaria digitata* between an oligotrophic and a eutrophic site in Abroath, Scotland (Davison *et al.*, 1984). *Laminaria digitata* does not accumulate the significant internal nutrient reserves seen in some other kelp. Higher growth rates have been associated with alga situated close to sewage outfalls. However, after removal of sewage pollution in the Firth of Forth, *Laminaria digitata* became abundant on rocky shores from which they had previously been absent (Read *et al.*, 1983).

Sensitivity assessment. The pressure benchmark is set at a level that is relatively protective and based on the evidence and considerations outlined above the biological assemblage is considered to be 'Not sensitive' at the pressure benchmark. Resistance and resilience are therefore assessed as 'High'.

Organic enrichment

High

Q: High A: High C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: High C: High

Organic deposition may result in siltation (see smothering and siltation change pressure) and subsequent re-suspension of organic particles reducing water clarity (see change in suspended solids pressure). The deposition of sewage effluent into coastal environments resulted in the absence of *Laminaria digitata* and many other species from the coastline of the Firth of Forth (Read *et al.*, 1983). The use of some kelp species in conjunction with fish aquaculture (to buffer the effects of organic enrichment in the local area) suggests that many commercial kelps (including *Laminaria digitata*) are tolerant to local increases in organic enrichment, although the level of enrichment experienced will be dependent on fish species and aquaculture design (Troell *et al.*, 2003).

Where the biotope occurs in tide swept or wave exposed areas (Connor *et al.*, 2004) water movements will disperse organic matter reducing the level of exposure. The key characterizing species *Corallina officinalis* has been noted to increase in abundance and may form extensive turfs within the vicinity of sewage outfalls and at intermediately polluted sites (Bellgrove *et al.*, 2010; Littler & Murray, 1975; May, 1985; Brown *et al.*, 1990; Bellgrove *et al.*, 1999). *Corallina elongata* and the crusting coralline *Lithophyllum incrustans* were present at sites dominated by *Ulva* spp. in the Mediterranean exposed to high levels of organic pollution from domestic sewage (Arévalo *et al.*, 2007). In the Mediterranean Salas *et al.* (2006) note that the presence of *Sargassum* is an indicator of good water quality but no further information was provided. As turf forming algae including the red algal turf and particularly *Corallina* spp. trap large amounts of sediment the turf is not considered sensitive to sedimentation. The turfs host a variety of associated species and deposit feeders amongst these would be able to consume inputs of organic matter.

Sensitivity assessment. Based on resistance to sedimentation, exposure to wave action, the presence of detrital consumers and the dominance of turfs in areas subject to sewage inputs,

resistance is assessed as 'High' and resilience as 'High' (by default). The biotope is therefore considered to be 'Not sensitive' to this pressure at the benchmark.

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
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The loss of hard substratum would remove the rockpool habitat and sediments would be unsuitable for the red algal turf, crustose corallines and other attached algae that characterize this biotope. Other associated species such as anemones and limpets would also be lost as these are associated with rock habitats. *Sargassum muticum* may occur on small pebbles or shells in sediments and also occurs on artificial structures and marine litter (Engelen *et al.*, 2015) and vegetative fragments have been found floating close to pontoons in Ireland (Minchin, 2007). Native species within the biotope may have settlement preferences for particular surface textures. *Corallina officinalis* shows optimal settlement on finely rough artificial substrata (0.5 - 1mm surface particle diameter). Although spores will settle and develop as crustose bases on smooth surfaces, fronds were only initiated on rough surfaces. *Corallina officinalis* settled on artificial substrata within one week in the field in summer months in New England (Harlin & Lindbergh 1977). However, in the laboratory fronds can grow from bases attached to smooth surfaces (Wiedeman pers comm. Previous MarLIN review). Similarly, tests with stone panels fixed to the sublittoral, mid-tide and high-tide levels of varying roughness found that *Ulva* species settle preferentially on smoother, fine grained substratum (chalk, mottled sandstone) and *Porphyra purpurea* on rougher, granulated substratum (limestone, granite, basaltic larvae) (Luther, 1976). The presences of small crevices that prevent grazing and limit the effects of desiccation and other environmental factors such as exposure to wave action and currents appears to be critical to the establishment of turfs of *Osmundea pinnatifida* (Prathey, 2001).

Changes in substratum type can also lead to indirect effects. For example, Shanks & Wright (1986) observed that limpet mortalities were much higher at sites where the supply of loose cobbles and pebbles were greater, leading to increased abrasion through wave action 'throwing' rocks onto surfaces. littorinids are found on a variety of shores, including sedimentary so a change in type may not significantly affect this species and some of the invertebrate species such as nematodes, amphipods and oligochaetes and polychaetes associated with sediments trapped in the *Corallina* turf are also found in sedimentary habitats

Sensitivity assessment. A change to a soft sedimentary or a free-draining artificial substratum would remove the habitat 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)	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
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Not relevant to biotopes occurring on bedrock.

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

Abrasion/disturbance of the surface of the substratum or seabed	Medium Q: High A: High C: High	High Q: High A: High C: High	Low Q: High A: Medium C: High
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The species characterizing this biotope occur on the rock and therefore have no shelter from abrasion at the surface. No direct evidence was found to assess the sensitivity of *Sargassum muticum* to this pressure.

Littler & Kauker, (1984) suggest that the basal crustose stage of *Corallina officinalis* is adaptive to resist sand scour and wave shearing (as well as physiological stressors such as desiccation and heating). The base is much tougher than the fronds shown by experiments that demonstrate that the base has nearly twice the mechanical resistance (measured by penetration) of fronds (Littler & Kauker, 1984). In general, studies show that *Corallina* and other turf forming algae appear to be relatively resistant to single events and low levels of trampling. Brosnan & Crumrine (1994), for example, found that in experimentally trampled plots the cover of foliose and canopy forming species declined while turf forming algae were relatively resistant. Similarly, a comparison of rocky intertidal ledges that received different amounts of visitors in Dorset, England, found that *Corallina officinalis* and encrusting corallines were present on both heavily visited and less visited ledges suggesting that these species has some resistance to trampling (Pinn & Rodgers, 2005). Povey & Keough (1991) in Mornington Peninsula, Australia investigated the effects of sustained trampling on intertidal coralline algal mats where upright branching *Corallina* spp. formed a turf with other red algae with sand and encrusting coralline algae between turfs. The experimental strips were 2 m long and 0.5 m wide. The percentage cover of upright *Corallina* spp. was significantly affected by 25 passages of a strip per day after 12 and 33 days. The algae appeared flattened and were shorter (1-2 cm high) compared with the low intensity and control plots (3-4 cm high). However low intensity trampling within a strip (2 passages/ day) did not significantly affect the Coralline turf. Fletcher and Frid (1996b; 1996a) noted a decrease in the understorey 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 (Hawkins and Harkin, 1985) by trampling.

Brown & Taylor (1999) also found that higher intensities of trampling damaged turfs. Moderate (50 steps per 0.09 sq. metres) or more trampling on intertidal articulated coralline algal turf in New Zealand reduced turf height by up to 50%, and weight of sand trapped within turf to about one third of controls. This resulted in declines in densities of the meiofaunal community within two days of trampling. Although the community returned to normal levels within 3 months of trampling events, it was suggested that the turf would take longer to recover its previous cover (Brown & Taylor 1999). Similarly, Schiel & Taylor (1999) noted that trampling had a direct detrimental effect on coralline turf species on the New Zealand rocky shore. At one site coralline bases were seen to peel from the rocks (Schiel & Taylor 1999), however, this was probably due to increased desiccation caused by loss of the algal canopy.

Tyler-Walters & Arnold (2008) found no information on the effects of trampling on *Laminaria* species (*Laminaria digitata* or *Saccharina latissima*). The authors reported that laminarians are robust species but that trampling on blades at low tide could potentially damage the blade or growing meristem.

Trawling, used to harvest *Laminaria hyperborea* in Norway results in whole alga being removed from the substratum, and substantial scouring of the substratum, indicating that the use of trawls in a *Laminaria digitata* biotope is likely to detrimentally affect the biotope, regardless of the target species.

Species associated with the biotope may be more sensitive. The limpets and littorinids that occur in this biotope, have some protection from hard shells or plates but abrasion may damage and kill individuals or detach these. Removal of limpets 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.

Povey & Keough (1991) in experiments on shores in Mornington peninsula, Victoria, Australia, found that, few individuals of the limpet *Cellana trasomerica*, (similar size to *Patella vulgata*) suffered damage or relocated following kicking and trampling experiments (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).

Sensitivity assessment. The impact of surface abrasion will depend on the footprint, duration and magnitude of the pressure. Based on evidence from the step experiments and the relative robustness of the *Corallina officinalis* turf and associated species, resistance, to a single abrasion event is assessed as 'Medium' and recovery as 'High', so that sensitivity is assessed as 'Low'. Resistance and resilience will be lower (and hence sensitivity greater) to abrasion events

that exert a greater crushing force and remove the bases than the trampling examples the assessment is based on. Increased abrasion that altered the density of grazers may enhance growth of red and green algae but this is not considered to alter the character of the biotope but may lead to changes at the sub-biotope level.

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 and epiflora occurring in tide pools on rock which is resistant to subsurface penetration. The assessment for abrasion at the surface only is therefore considered to equally represent sensitivity to this pressure.

Changes in suspended solids (water clarity)

High

Q: Low A: NR C: NR

High

Q: High A: High C: High

Not sensitive

Q: Low A: Low C: Low

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). In general, increased suspended particles reduce light penetration and increase scour and deposition. They may enhance food supply to filter or deposit feeders (where the particles are organic in origin) or decrease feeding efficiency (where the particles are inorganic and require greater filtration efforts). No direct evidence was found to assess *Sargassum muticum*. As this species is buoyant and floats on the surface of rockpools it is considered to be relatively resistant to an increase in suspended sediments at the pressure benchmark, although some sublethal reductions in photosynthesis may occur due to decreased light penetration on lower branches and increased scour on tissues.

Increases in the cover of sediment trapping, turf forming algae at the expense of canopy forming species has been observed worldwide in temperate systems and has been linked to increased suspended solids linked to human activities worldwide (Airoidi, 2003). *Corallina* species accumulate more sediment than any other alga (Hicks, 1985). Hence an increase in suspended sediment is likely to accumulate in the coralline turf. A significant increase may result in smothering (see above). An accumulation of sediment within the turf may attract more sediment dwelling interstitial invertebrates such as nematodes, harpacticoids and polychaetes, although in more wave exposed locations accumulation of sediment is likely to be minimal. Increased suspended sediment may also result in increased scour, which may adversely affect foliose red algae, and interfere with settling spores and recruitment if the factor is coincident with their major reproductive period. However, coralline algae, especially the crustose forms are thought to be resistant of sediment scour (Littler & Kauker, 1984), and will probably not be adversely affected at the benchmark level. Therefore, an increase in suspended sediment may reduce the epiphytic species diversity in the immediacy, and adversely affect the cover of fleshy red algae and an intolerance of intermediate has been recorded. Recoverability is likely to be very high as species are likely to remain *in situ* from which recruitment can occur.

Red algae and coralline algae especially are known to be shade tolerant and are common components of the understory on seaweed dominated shores. Therefore, a decrease in light intensity is unlikely to adversely affect the biotope. An increase in light intensity is unlikely to adversely affect the biotope as plants can acclimate to different light levels. In the Bay of Fundy,

where the tidal flux of nutrients from the marshes includes a high level of suspended sediment *Palmaria palmata* grows well despite high turbidity. Irvine (1983) has also observed morphological adaptation of the plant in fairly sheltered, silty conditions. Sometimes the blade divisions are wedge-shaped and finely dissected above or the blade has numerous linear divisions throughout. It is likely that this form reduces possible smothering that may result from increased siltation resulting from increased levels of suspended sediments. In the absence of nutrients short-term increase in turbidity may affect growth and reproduction, however, as a perennial, the adults will probably survive.

Experiments have shown that the associated green algae are shade tolerant 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. Therefore, a decrease in light intensity is unlikely to adversely affect the biotope. An increase in light intensity is unlikely to adversely affect the biotope as plants can acclimate to different light levels

The absence of *Laminaria digitata* in the Firth of Forth was suggested to be caused by the outflow from a sewage treatment plant that increased the turbidity of the water and thus decreased photosynthetic activity, although the effect of turbidity was probably coupled with increased nutrient levels (Read *et al.*, 1983). Blue light is crucial for the gametophytic stages of *Laminaria digitata*, and several other congeneric species (Lüning, 1980). Dissolved organic materials (yellow substance or gelbstoff) absorbs blue light (Kirk, 1976), therefore changes in riverine input or other land based runoff are likely to influence kelp density and distribution. In the silt-laden waters around Helgoland, Germany the depth limit for *Laminaria digitata* growth may be reduced to between 0 m and 1.5 m (Birkett *et al.* 1998b). In locations where water clarity is severely decreased, *Laminaria* species experience a significant decrease in growth from the shading of suspended matter and/or phytoplankton (Lyngby & Mortensen 1996, Spilmont *et al.*, 2009).

This community is unlikely to be dependent on suspended sediment. Although accumulated sediment within coralline turf habitats is likely to increase the species diversity of the epiphytic fauna, in very wave exposed locations, accumulated sediment in the habitat is likely to be minimal. A reduction in suspended sediment will probably reduce the risk of scour, and reduce food availability (where particles are organic) for the few suspension feeding species in the biotope (e.g. barnacles and spirorbids), although effects are not likely to be lethal.

Sensitivity assessment. The exposure of biotope to suspended sediments in the water column will be limited to immersion periods, and wave action will reduce accumulation. The biotope is considered to be 'Not sensitive' to a reduction in suspended solids, although this may reduce food supply to the barnacles and other filter feeders that occur in this biotope. An increase in suspended solids may lead to some sub-lethal abrasion of fronds however, evidence globally indicates that increase suspended solids favour the turf-forming algae that characterize this biotope (Airoldi, 2003). Resistance is therefore assessed as 'High' and resilience as 'High' (by default) so that the biotope is considered to be 'Not sensitive'. An increase in suspended solids above the pressure benchmark may result in a change in species composition with an increase in species seen in very turbid, silty environments e.g. *Ahnfeltia plicata*, *Rhodothamniella floridula*, *Polyides rotunda* and *Furcellaria lumbricalis*.

Smothering and siltation rate changes (light)

Low

Q: Low A: NR C: NR

Medium

Q: High A: Medium C: High

Medium

Q: Low A: Low C: Low

Corallina officinalis and others within the genus (e.g. *Corallina pinnatifolia* and *Corallina vancouveriensis*) are found on shores subject to high rates of sedimentation that are periodically disturbed by sand burial and scour (Stewart, 1989). Coralline turfs also trap sediments within the turf. The amount of sediment present and the associated fauna varies naturally depending on local conditions such as wave exposure (Dommasnes, 1969). On intertidal shores in southern California the amount of sediment trapped within turfs of *Corallina* spp. varied seasonally from < 5mm to >4.5 cm and was closely related to species composition and the structure of the turf. Airoidi (2003) identified a number of morphological, physiological and life history traits that conferred high levels of tolerance to sedimentation. Those shared by *Corallina* spp are the regeneration of upright fronds from a perennial basal crust resistant to burial and scour, calcified thalli, apical meristems, large reproductive outputs, lateral vegetative growth and slow growth rates (Airoidi, 2003).

In a review of the effects of sedimentation on rocky coast assemblages, Airoidi (2003) outlined the evidence for the sensitivity of coralline algae to sedimentation. The reported results are contradictory with some authors suggesting that coralline algae are negatively affected by sediments while others report that encrusting corallines are often abundant or even dominant in a variety of sediment impacted habitats (Airoidi, 2003 and references therein). Crustose corallines have been reported to survive under a turf of filamentous algae and sediment for 58 days (the duration of experiment) in the Galapagos (species not identified, Kendrick, 1991). The crustose coralline *Hydrolithon reinboldii*, has also been reported to survive deposition of silty sediments on subtidal reefs off Hawaii (Littler, 1973).

Atalah & Crowe (2010) added sediment to rockpools to test the effects of sedimentation experimentally. The rockpools were occupied by a range of algae including encrusting corallines and turfs of *Mastocarpus stellatus*, *Chondrus crispus* and *Corallina officinalis* and green and red filamentous algae. Sediment treatments involved the addition of a mixture of coarse and fine sand of either 300 mg/cm²/month or 600 mg/cm² every 15 days. The treatments were applied for seven months and experimental conditions were maintained every two weeks. The experimental treatments do not directly relate to the pressure benchmark but indicate some general trends in sensitivity. In the pools the chronic addition of both levels of sediment led to a significant increase in the cover of *Corallina officinalis*, green filamentous algae (*Ulva* sp.) and red turfing algae while crustose coralline algae decreased. Sedimentation led to an increase in the mean cover of red turfing algae (*Mastocarpus stellatus* and *Chondrus crispus* and *Corallina officinalis*) from 11.7% (±1.0 S.E.) in controls to 26.1% (±4.7 S.E.) in sedimented assemblages, but there were no differences between the two levels of sedimentation (Atalah & Crowe, 2010). The results suggest that some of the species found in this biotope (*Corallina officinalis* and *Chondrus crispus*) are tolerant of chronic levels of low sedimentation.

The associated species, *Patella vulgata* and *Littorina* spp. are likely to be negatively affected by siltation (Airoidi & Hawkins, 2007; Chandrasekara & Frid, 1998; Albrecht & Reise, 1994). Experiments have shown that the addition of even thin layers of sediment (approximately 4 mm) inhibit limpet grazing and result in loss of attachment and death after a few days Airoidi & 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 (Airoidi & 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 turf-forming species are generally tolerant of some sedimentation but the threshold in relation to the benchmark is not easily determined, especially as this biotope

occurs in rockpools which may increase the exposure. Deposition of 5 cm of fine material (see benchmark) in a single incident is unlikely to result in significant mortality before sediments are removed by current and wave action. Burial will lower survival and germination rates of algal spores and may lead to some mortality of spores and early stages of foliose red algae. Adults are more resistant but will experience a short-term decrease in growth and photosynthetic rates. Resistance is assessed as 'Medium' based on rapid removal of the majority of smothering sediments within a couple of tidal cycles, resistance will be lower where sediment remains in place for longer. Resilience is assessed as 'High' as holdfasts of *Sargassum muticum* and crustose bases of the characterizing red algae will remain and regeneration and vegetative growth will repair turfs. Overall the biotope is considered to have 'Low' sensitivity to smothering at the level of the benchmark. It should be noted that the associated *Patella vulgata* and littorinids have higher sensitivities to this pressure and that removal of these species may result in changes in algal composition and abundances through indirect grazing effects. The encrusting corallines may be sensitive to sedimentation but the level of sensitivity is difficult to ascertain from the evidence base. The encrusting corallines and grazers are considered to have 'Low' resistance to this pressure and 'medium' resilience, while the algal turf is considered to have 'Medium' resistance and 'High' resilience. The overall biotope sensitivity assessment of 'Low' is presented in the sensitivity assessment table. Increased chronic siltation may lead to changes in assemblage and replacement by species more tolerant of scour such as *Rhodothamniella floridula*. Confidence in the assessment is 'Low' due to the lack of direct evidence for the key characterizing species *Sargassum muticum*.

Smothering and siltation rate changes (heavy)

Low

Q: Low A: NR C: NR

High

Q: High A: Low C: Medium

Low

Q: Low A: Low C: Low

The available evidence for siltation pressures is outlined for the 'light' deposition pressure. At the pressure benchmark 'heavy deposition' represents a considerable thickness of deposit and may fill shallow pools. Complete burial of algal turf and encrusting corallines and associated animals would occur and it is likely that most of the *Sargassum muticum* and kelps would be smothered. 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 wave and tides rather than removed and this will result in considerable scour. However, mortality will depend on the duration of smothering, where wave action rapidly mobilises and removes fine sediments, survival may be much greater. No evidence was found to assess this pressure at the benchmark, even the most tolerant of organisms would eventually suffer from inhibition and mortality following smothering although the thresholds for these effects have not been identified (Airoldi, 2003). A deposit at the pressure benchmark would cover species with a thick layer of fine materials. Species associated with this biotope such as limpets and littorinids would not be able to escape from deposits and would likely suffer mortality (see evidence for light siltation).

Sensitivity assessment. At the level of the benchmark (30 cm of fine material added to the seabed in a single event) smothering is likely to result in mortalities of macroalgae, particularly germlings, and the loss of invertebrate grazers. Resistance is assessed as 'Low' as many individuals exposed to siltation at the benchmark level are predicted to die and resilience is assessed as 'High' as holdfasts of *Sargassum muticum* and crustose bases of the red algae turf forming species are likely to survive and provide a mechanism for recovery through vegetative growth. Overall the biotope has a 'Low' sensitivity to siltation at the pressure benchmark, based on rapid recovery. It should be noted that

the associated *Patella vulgata* and littorinids may have higher sensitivities to this pressure and that if these species are removed over a large area, changes in algal composition and abundance may result and are likely to include a greater abundance of green algae until grazing levels are re-established. Confidence in the resistance is assessed as 'Low' due to the lack of evidence for sedimentation at the pressure benchmark.

Litter	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR
	Not assessed.		
Electromagnetic changes	No evidence (NEv) Q: NR A: NR C: NR	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: Low C: High	High Q: High A: High C: High	Not sensitive Q: High A: Low C: High

Shading of shallow examples of the biotope (e.g. by the construction of pontoons or jetties) would limit the availability of light, and have similar effects to that of increased turbidity (see above) in the affected area. *Sargassum muticum* and kelp species are likely to be excluded, while shade tolerant red algae may increase in abundance, or be reduced to encrusting corallines or faunal turfs depending on the degree of shading.

Coralline crusts and Corallina officinalis are shade tolerant algae, often occurring under a macroalgal canopy that reduces light penetration. These species can acclimate to different levels of light intensity and quality and encrusting corallines can occur in deeper water than other algae where light penetration is limited. Samples of *Lithophyllum impressum* suspended from a raft and shaded (50-75% light reduction) continued to grow over two years (Dethier, 1994). In areas of higher light levels, the fronds may be lighter in colour due to bleaching (Colhart & Johansen, 1973). Other red algae in the biotope are flexible with regard to light levels and can also acclimate to different light levels. Canopy removal experiments in a rocky sub tidal habitat in Nova Scotia, Canada by Schmidt & Scheibling (2007) did not find a shift in understorey macroalgal turfs (dominated by *Corallina officinalis*, *Chondrus crispus* and *Mastocarpus stellatus*) to more light-adapted species over 18 months.

Prathep (2001) observed higher growth rates of *Osmundea pinnatifida* turfs on the Isle of Man in winter when irradiance was lowest (average 28 $\mu\text{mol}/\text{m}^2/\text{s}$). In summer when irradiance was higher

(average 1194 $\mu\text{mol}/\text{m}^2/\text{s}$) fronds were bleached. Photoinhibition of photosynthesis was observed in submerged plants at irradiances of 1200 $\mu\text{mol}/\text{m}^2/\text{s}$ and some tips became bleached after exposure for 35-40 minutes (Pratsep, 2001). Experimental tests established that irradiance rather than desiccation resulting from higher temperatures is responsible for the observed bleaching. Artificial shades placed above *Osmundea pinnatifida* turfs occurring on Isle of Man shores for 1 month (mid-April-mid-March) did not reduce desiccation but no bleaching occurred in shaded turfs (compared to unshaded) indicating that irradiance, rather than desiccation results in the observed bleaching of fronds (Pratsep, 2001).

Sensitivity assessment. Shading may lead to the biotope reverting to LR.FLR.Rkp.Cor.Cor through the loss of *Sargassum muticum* and kelps, hence a resistance of 'Low' is suggested, with a resilience of 'High' (based on *Sargassum muticum* and kelps and lack of effect on red algae). Biotope sensitivity is judged to be 'Low'.

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

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. Barriers and changes in tidal excursion are not considered relevant to the characterizing crusting corallines and *Corallina officinalis* as species dispersal is limited by the rapid rate of settlement and vegetative growth from bases rather than reliance on recruitment from outside of populations. *Sargassum muticum* and other species associated with the biotope such as *Ulva* spp. are widely distributed and can produce large numbers of fragments/propagules or larvae capable of long distance transport and survival, 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

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

Sargassum muticum as an invasive species is not licensed for cultivation. No information was found

on current production of *Chondrus crispus* or other turf forming red seaweeds in the UK and it is understood that wild harvesting rather than cultivation is the method of production for these and littorinids. No evidence was found for the effects of gene flow between cultivated species and wild populations. Although cultivation of different genotypes may lead to gene flow between wild and cultivated populations the limited dispersal may reduce exposure. Some negative effects may arise from hybridisation between very geographically separated populations but there is no evidence to suggest that gene flow between different UK haplotypes would lead to negative effects. *Sargassum muticum* can spread over greater spatial distances than red species through drifting of fragments and therefore populations would not be considered to be reproductively isolated. This pressure is therefore considered 'Not relevant' to this biotope group.

Introduction or spread of invasive non-indigenous species

Low

Q: High A: Medium C: High

Very Low

Q: Low A: NR C: NR

High

Q: Low A: Low C: Low

Within rockpools temperature and salinity may be subject to rapid variation and these conditions will largely exclude species that are adapted to more stable, subtidal environments. Invasive non-indigenous species (INIS) that can alter habitats (ecological engineers), or out-compete native macroalgae for space and other resources such as light and nutrients, are the most likely species to negatively affect this biotope. Space pre-emption by *Sargassum muticum* and shading may prevent further settlement of INIS until disturbance events create gaps for invasion. It should be noted that *Sargassum muticum* is a very successful invasive species and this biotope represents a change from a natural indigenous assemblage.

Algal species which may have overlapping habitat requirements include the green seaweed *Codium fragile* subsp. *tomentosoides* (now renamed as *Codium fragile fragile*) and the red seaweed *Heterosiphonia japonica*, neither of these have so far been recorded in nuisance densities (Sweet, 2011j). Beneath a canopy of the invasive *Codium fragile* ssp. *tomentosoides* on subtidal rocky shores in Nova Scotia, *Corallina officinalis* was the dominant species comprising 78-80% of the turf biomass, while *Chondrus crispus* and *Mastocarpus stellatus* comprised 18% (Schmidt & Scheibling, 2007). The biomass of *Corallina officinalis* was similar to those under a canopy of the native *Laminaria* species on the same shore (*Laminaria longicuris* and *Laminaria digitata*), suggesting little negative effect on turf forming algae. The red seaweeds *Heterosiphonia japonica* and *Neosiphonia harveyi* may also occur in this biotope but again no impacts have been reported.

The red seaweed *Grateloupia turuturu* occurs on the lower shore in pools. No ecosystem impacts have been reported in Great Britain; however this large, fast-growing seaweed may have the potential to displace native seaweed species and shade neighbouring species. In North America this species is a major competitor of *Chondrus crispus* which provides an important winter food source for littorinids and other invertebrates. As *Grateloupia turuturu* dies-back in the winter, the displacement of other species may therefore affect grazers (Sweet, 2011g).

In the Mediterranean crustose corallines and algal turfs facilitate attachment of *Caulerpa racemosa* by providing a more complex substratum than bare rock (Bulleri & Benedetti-Cecchi, 2008).

The tunicates *Didemnum vexillum* and *Asterocarpa humilis*, the hydroid *Schizoporella japonica* and the bryozoan *Watersipora subatra* (Bishop, 2012c, Bishop, 2015a and b; Wood, 2015) are currently only recorded from artificial hard substratum in the UK and it is not clear what their established

range and impacts in the UK would be. *Didemnum vexillum* occurs in tide pools in other areas where it has become established (Bishop, 2012c) and can have substantial effects on communities, similarly the tunicates *Corella eumyota* and *Botrylloides violaceus* can smother rock habitats (Bishop, 2011b and 2012b).

A significant potential INIS is the Pacific oyster *Magallana gigas*, as its distribution and environmental tolerances are considered to overlap with this biotope and this reef forming species can alter habitat structure. This species may also affect the grazers present in the biotope. No evidence was found for effects on rock pools, although on the Mediterranean coast *Magallana gigas* is cultivated in micro-tidal lagoons and has established wild populations (Miossec *et al.*, 2009, cited from Herbert *et al.*, 2012). In the Wadden Sea and North Sea, *Magallana gigas* overgrows mussel beds in the intertidal zone (Diederich, 2005, 2006; Kochmann *et al.*, 2008), although larvae did show preference for settling on conspecifics before the mussels and struggled to settle on mussels with a fucoid covering. It has been observed that mussel beds in the Wadden Sea that are adjacent to oyster farms were quickly converted to oyster beds (Kochmann *et al.*, 2008). Dense aggregations of *Magallana gigas* on a former mussel bed showed increased abundance and biomass of *Littorina littorea* in the Wadden Sea (Markert *et al.* 2010). However, Eschweiler & Buschbaum (2011) found that juvenile *Littorina littorea* could carry *Magallana gigas* and *Crepidula fornicata* as epibionts. Body dry weight of snails without oyster overgrowth was twice as high compared to winkles covered with oysters. Also crawling speed of snails with oyster epigrowth was significantly slowed down and about ten times lower than in unfouled periwinkles. Additionally, oyster epibionts caused a strong decrease in reproductive output. In laboratory experiments, egg production of fouled *Littorina littorea* was about 100-fold lower than in affected individuals. Field surveys in different years and habitats demonstrated that up to 10% of individuals occurring on epibenthic bivalve beds and up to 25% of snails living on sand flats may be fouled by *Magallana gigas*. *Sargassum muticum* is likely to have been imported to Europe in association with *Magallana gigas* imports (Engelen *et al.*, 2015). *Sargassum muticum* can grow on shells and pebbles and *Magallana* shells would provide a suitable habitat. However the loss of the rockpool would represent a significant change to the biotope.

The non-native crab *Hemigrapsus sanguineus* has recently been recorded in the UK (Sweet & Sewell, 2014) and has the potential to be a significant predator of intertidal invertebrates. Significant reductions in common shore crab abundance and mussel density have been reported where the Asian shore crab has achieved high densities in mainland Europe (Sweet & Sewell, 2014). In Rye, New York, declines of approximately 80% of *Littorina littorea* in the intertidal were reported to coincide with an expansion of the *Hemigrapsus sanguineus* population (Kraemer *et al.*, 2007). This crab occurs on exposed shores and may therefore occur in this biotope when established. If predation of littorinids was significantly increased this could impact the algal composition and abundance of this biotope by altering the level of grazing pressure.

Sensitivity assessment. This biotope is defined by the presence of the INIS *Sargassum muticum*. This species can shade the biotope and out-compete native species by its ability to rapidly colonize newly created gaps and its high growth rate. Little evidence was found to assess the impact of INIS on this biotope and much of the evidence comes from intertidal habitats in other countries. The conversion of this biotope to a *Magallana gigas* reef would present a significantly negative impact. Replacement of red algal turfs by other similar species may lead to some subtle effects on local ecology but at low abundances the biotope would still be recognisable from the description. Based on *Magallana gigas*, resistance to this pressure is assessed as 'Low'. The biotope will only recover if this species are removed, either through active management or natural processes. To recognise that recovery may be prolonged, resilience is assessed as 'Very Low' and sensitivity is, therefore,

assessed as 'High'.

Introduction of microbial pathogens

Q: High A: High C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: High C: High

No evidence was found on the susceptibility of *Sargassum muticum* to pathogens. Several coralline and non-coralline species are epiphytic on *Corallina officinalis*. Irvine & Chamberlain (1994) cite tissue destruction caused by *Titanoderma corallinae*. However, no information on pathogenic organisms in the UK was found. In Rhodophyta, viruses have been identified by means of electron microscopy (Lee, 1971) and they are probably widespread. However, nothing is known of their effects on growth or reproduction in red algae and experimental transfer from an infected to an uninfected specimen has not been achieved (Dixon & Irvine, 1977). *Corallina officinalis*, like many other algal species has been demonstrated to produce antibacterial substances (Taskin *et al.*, 2007). Diseased encrusting corallines were first observed in the tropics in the early 1990's when the bacterial pathogen Coralline Lethal Orange Disease (CLOD) was discovered (Littler & Littler, 1995). All species of articulated and crustose species tested to date are easily infected by CLOD and it has been increasing in occurrence at sites where first observed and spreading through the tropics. Another bacterial pathogen causing a similar CLOD disease has been observed with a greater distribution and a black fungal pathogen first discovered in American Samoa has been dispersing (Littler & Littler, 1998). An unknown pathogen has also been reported to lead to white 'target-shaped' marks on crusting corallines, again in the tropic (Littler *et al.*, 2007). No evidence was found that these are impacting temperate coralline habitats.

Symptoms of disease are regularly seen on *Laminaria* species, however little evidence in the literature is apparent. Infection of *Laminaria japonica* sporophytes by *Pseudoalteromonas*, *Vibrio* and *Halomonas* results in the characteristic symptoms of hole-rotten disease (Wang *et al.*, 2008). Additionally red spot disease may be caused by bacteria of the genus *Alteromonas* (Sawabe *et al.*, 1998). Hyperplasia or gall growths are often seen as dark spots on *Laminaria digitata* and have been associated with endophytic brown filamentous algae. It can be inferred from these observations that microbial pathogens may impact growth rates of individuals. There is no evidence in the literature that infection by microbial pathogens results in mass death of *Laminaria* populations and the kelp themselves are known to regulate bacterial infections through iodine metabolism (Cosse *et al.*, 2009).

Other species associated with this biotope such as littorinids, patellid limpets and other algae also experience low levels of infestation by pathogens but mass-mortalities have not been recorded. For example, parasitism by trematodes may cause sterility in *Littorina littorea*. *Littorina littorea* are also parasitized by the boring polychaete, *Polydora ciliata* and *Cliona sp*, which weakens the shell and increases crab predation.

Craigie & Correa (1996) described 'green spot' disease in *Chondrus crispus*, caused by the interaction of several biotic agents including fungi, bacteria, algal endophytes and grazers, and resulting in tissue necrosis. Correa & McLachlan (1992) infected *Chondrus crispus* with the green algal endophytes *Acrochaete operculata* and *Acrochaete heteroclada*. Infections resulted in detrimental effects on host performance, including slower growth, reduced carrageenan yield, reduced generation capacity and tissue damage. Stanley (1992) described the fungus *Lautita danica* being parasitic on cystocarpic *Chondrus crispus* and Molina (1986) was the first to report *Petersenia pollagaster*, a fungal invasive pathogen of cultivated *Chondrus crispus*. At usual

levels of infestation in wild populations these are not considered to lead to high levels of mortality.

The fungal pathogen, *Petersenia palmaria* n. sp (Oomycetes) which infects *Palmaria mollis*, does not affect *Palmaria palmata* (Meer & Pueschel, 1985). Other species associated with this biotope such as littorinids, patellid limpets and other algae also experience low levels of infestation by pathogens but mass-mortalities have not been recorded. For example, parasitism by trematodes may cause sterility in *Littorina littorea*. *Littorina littorea* are also parasitized by the boring polychaete, *Polydora ciliata* and *Cliona* sp, which weakens the shell and increases crab predation.

Sensitivity assessment. Based on the lack of reported infection and mortality in *Sargassum muticum* and temperate coralline habitats, resistance of this biotope is assessed as 'High' and resilience as 'High' by default. Although currently considered 'Not sensitive' this assessment may require updating in the future if the currently tropical pathogens spread.

Removal of target species

Low

Q: High A: High C: High

High

Q: High A: High C: High

Low

Q: High A: High C: High

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. A number of species present in the biotope may be harvested recreationally or commercially. The Seaweed Industry Association (www.seaweedindustry.com) report that *Sargassum muticum* is often gathered from the shore or floating mats to be used as fertilizer or compost and that many coastal populations make use of *Sargassum* as food source. Other seaweeds within the biotope can be harvested to produce compounds used in a variety of applications such as thickening and stabilizing agents in the food industry. The key characterizing and structuring species *Corallina officinalis* is collected for medical purposes; the fronds are dried and converted to hydroxyapatite and used as bone forming material (Ewers *et al.*, 1987).

Red and green algae may also be collected, *Chondrus crispus* is harvested commercially in Scotland and Ireland, the stipe is removed but the base is left intact to allow the algae to re-grow. *Palmaria palmata* and *Osmundea pinnatifida* are also collected by hand commercially and recreationally for consumption. The effect of harvesting *Chondrus crispus* has been best studied in Canada. Prior to 1980, the seaweed beds of Prince Edward Island were dominated by *Chondrus crispus* and the species was heavily exploited. The authors suggested that harvesting had brought about a shift in community structure following a marked increase in abundance of another red seaweed, *Furcellaria lumbricalis*, which is avoided by the commercial harvest with an associated decline in abundance of *Chondrus crispus* (Sharp *et al.*, 1993). Sharp *et al.* (1986) reported that the first drag rake harvest of the season, on a Nova Scotian *Chondrus crispus* bed, removed 11% of the fronds and 40% of the biomass. Efficiency declined as the harvesting season progressed. Chopin *et al.* (1988) noted that non-drag raked beds of *Chondrus crispus* in the Gulf of St Lawrence showed greater year round carposporangial reproductive capacity than a drag raked bed. In the short-term, therefore, harvesting of *Chondrus crispus* may remove biomass and impair reproductive capacity, while in the long-term, it has the potential to alter community structure and change the dominant species. Removal of other associated algae such as *Palmaria palmata* and *Osmundea pinnatifida* will reduce cover of turf forming red algae in this biotope. Garbary *et al.*, (2012) studied harvested and non-harvested shores in Nova Scotia, Canada containing stands of *Palmaria palmata*. They also conducted experimental removal of *Palmaria palmata* and assessed simulated removal of

Palmaria palmata by an experienced commercial harvester. Simulated commercial harvesting reduced cover of *Palmaria palmata* from 70% to 40%, although experimental removal on shores that were not usually harvested reduced cover to 20% (Garbary *et al.*, 2012).

Littorinids are one of the most commonly harvested species of the rocky shore. Large scale removal of *Littorina littorea* may allow a proliferation of opportunistic green algae, such as *Ulva*, on which it preferentially feeds. Experiments designed to test the effects of harvesting by removing individuals at Strangford Lough found that there was no effect of experimental treatments (either harvesting or simulated disturbance) on *Littorina littorea* abundance or body size over a 12 week period (Crossthwaite *et al.* 2012). This suggests that these animals are generally abundant and highly mobile; thus, animals that were removed were quickly replaced by dispersal from surrounding, un-harvested areas. However, long-term exploitation, as inferred by background levels of harvest intensity, did significantly influence population abundance and age structure (Crossthwaite *et al.* 2012). A broadscale study of harvesting in Ireland using field studies and interviews with wholesalers and pickers did suggest that some areas were over harvested but the lack of background data and quantitative records make this assertion difficult to test (Cummins *et al.*, 2002). Changes in grazer abundance can alter the character of the assemblage.

Sensitivity assessment. The key characterizing species and a number of the associated species are harvested, this may alter the character of the biotope resulting in reclassification. The removal of *Sargassum muticum* will lead to reclassification to a similar biotope such as LR.FLR.Rkp.Cor.Cor, although these changes may be short-lived where recovery occurs from holdfasts. Removal of *Corallina officinalis* and red and green algae will lead to changes in the character of the biotope but it is unlikely selective targeted harvesting of these species would lead to biotope reclassification as other similar species would increase in abundance. Removal of the associated limpet and littorinid grazers may allow red and green algae to increase in abundance and density. However, these algae may also be subject to harvesting limiting their dominance. Biotope resistance is assessed as 'Low' as the species are readily harvested and removed, recovery is assessed as 'High', based on resilience of *Sargassum muticum* and regrowth of species from holdfasts with compensation between red and green algae. Sensitivity is therefore judged to be 'Low'.

Removal of non-target species

Low

Q: Low A: NR C: NR

High

Q: High A: Low C: Low

Low

Q: Low A: Low C: Low

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 non-target species on this biotope. The biotope is characterized by epilithic algae which have no protection from removal by human activities that result in this pressure. Incidental removal of the key characterizing species and associated species would alter the character of the biotope. The biotope is characterized by the invasive species *Sargassum muticum* and *Corallina officinalis* and other associated species. The loss of the biological assemblage due to incidental removal as by-catch would therefore alter the character of the habitat and result in the loss of species richness. The ecological services such as primary production and the habitat provided by these species would also be lost.

Sensitivity assessment. Removal of a large percentage of the characterizing species resulting in bare rock would alter the character of the biotope, species richness and ecosystem function. Resistance is, therefore, assessed as 'Low'. Resilience is assessed as 'High' as the biotope

is considered to recover more rapidly than similar rockpool biotopes such as LR.FLR.Rkp.Cor.Cor and LR.FLR.Rkp.Cor.Bif due to the rapid establishment and growth of *Sargassum muticum*. Sensitivity is, therefore, assessed as 'Low'.

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