



# MarLIN

## Marine Information Network

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

# Foliose seaweeds and coralline crusts in surge gully entrances

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

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**Please note.** This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [<https://www.marlin.ac.uk/habitats/detail/31>]. All terms and the MarESA methodology are outlined on the website (<https://www.marlin.ac.uk>)

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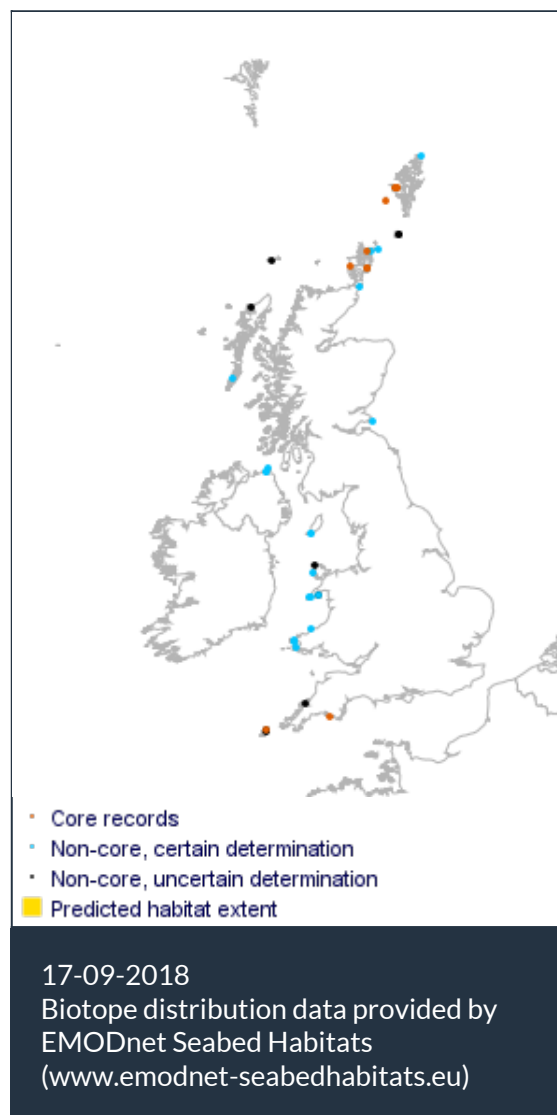


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**Foliose seaweeds and coralline crusts in surge gully entrances**  
 Photographer: Christine Howson  
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Researched by Dr Heidi Tillin      Refereed by Admin

## Summary

### ☰ UK and Ireland classification

<b>EUNIS 2008</b>	A3.711	Foliose seaweeds and coralline crusts in surge gully entrances
<b>JNCC 2015</b>	IR.FIR.SG.FoSwCC	Foliose seaweeds and coralline crusts in surge gully entrances
<b>JNCC 2004</b>	IR.FIR.SG.FoSwCC	Foliose seaweeds and coralline crusts in surge gully entrances
<b>1997 Biotope</b>	IR.EIR.SG.FoSwCC	Foliose seaweeds and coralline crusts in surge gully entrances

### 🔍 Description

This biotope is found on steep wave-surged entrances to gullies and caves and on unstable boulders in the entrance to caves and gullies. The rock may be abraded by the movement of the boulders and cobbles in heavy surge and tends to be dominated by dense foliose seaweeds that grow rapidly in the calmer summer months. Beneath the foliose seaweeds the rock surface is typically covered with coralline crusts, which are longer-lived, and tolerant of abrasion. The flora of this biotope is relatively varied, depending upon the amount of light and degree of abrasion or rock

mobility with red seaweeds such as *Cryptopleura ramosa*, *Plocamium cartilagineum*, *Odonthalia dentata*, *Callophyllis laciniata*, *Phycodrys rubens*, *Hypoglossum hypoglossoides*, *Phyllophora crispa* and *Corallina officinalis*. The brown seaweed *Dictyota dichotoma* also occurs in these conditions, since it is tolerant of some sand scour. During the summer months small fast-growing kelp plants can arise in this biotope, although the mobility of the substratum prevents the kelp from forming a kelp forest. Dense swathes of very young kelp such as *Laminaria hyperborea* are, however, not uncommon. The faunal community consist of the anemone *Urticina felina*, the sponge *Halichondria panicea* and the ascidian *Dendrodoa grossularia*. More mobile fauna include the echinoderms *Asterias rubens* and *Echinus esculentus*, the top shell *Gibbula cineraria* and the crab *Cancer pagurus* (Connor *et al.*, 2004; [JNCC](#))

### ↓ Depth range

0-5 m, 5-10 m

### 🏛️ Additional information

-

### ✓ Listed By

- none -

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## Sensitivity review

### Sensitivity characteristics of the habitat and relevant characteristic species

The biotope description and characterizing species is taken from Connor *et al.*, (2004). This biotope is found on steep wave-surfed entrances to gullies and caves and on unstable boulders in the entrance to caves and gullies. The rock may be abraded by the movement of the boulders and cobbles in heavy surge and tends to be dominated by dense foliose red seaweeds that grow rapidly in the calmer summer months. Beneath the foliose seaweeds the rock surface is typically covered with coralline crusts, which are longer-lived, and tolerant of abrasion. The flora of this biotope is relatively varied, depending upon the amount of light and degree of abrasion or rock mobility with red seaweeds such as *Cryptopleura ramosa*, *Plocamium cartilagineum*, *Odonthalia dentata*, *Callophyllis laciniata*, *Phycodrys rubens*, *Hypoglossum hypoglossoides*, *Phyllophora crispa* and *Corallina officinalis*. The brown seaweed *Dictyota dichotoma* also occurs in these conditions, since it is tolerant of some sand scour. As the key characterizing species that define and structure the biotope, evidence for the sensitivity of these species is considered in the sensitivity assessments.

During the summer months small fast-growing kelp plants can arise in this biotope, although the mobility of the substratum prevents the kelp from forming a kelp forest. Dense swathes of very young kelp such as *Laminaria hyperborea* are, however, not uncommon, these species are not considered to characterize the biotope and are not considered within the assessments. The faunal community consist of the anemone *Urticina felina*, the sponge *Halichondria panicea* and the ascidian *Dendrodoa grossularia*, the sensitivity of these species is considered generally within the sensitivity assessments. More mobile fauna include the echinoderms *Asterias rubens* and *Echinus esculentus*, the top shell *Gibbula cineraria* and the crab *Cancer pagurus*. The sensitivity of *Echinus esculentus* and the top shell are described generally in the sensitivity assessments as these species can structure biotopes by grazing on the algal turf and removing epifaunal recruits (Turner & Todd, 1991). Where grazing levels are high only coralline crusts may be present as the growing meristem is sheltered under the coralline surface and therefore resistant to grazing (Littler & Kitching, 1996).

Water movement and abrasion resulting from sediment instability are key factors structuring the biotope and significant alteration to these is likely to change the character of the biotope. Where pressures may alter these factors this is identified and discussed within the sensitivity assessments

### Resilience and recovery rates of habitat

The red algae (Rhodophyta) and the brown algae *Dictyota dichotoma* that characterize this biotope have complex life histories and exhibit distinct morphological stages over the reproductive life history. Alternation occurs between asexual spore producing stages (tetrasporophytes) and male and female plants producing sexually. Life history stages can be morphologically different or very similar. Red algae life stages may include prostrate creeping bases that function as a holdfast as in *Corallina officinalis* and *Plocamium cartilagineum* whereas in other species present in the biotope such as *Callophyllis laciniata*, *Phycodrys rubens*, *Odonthalia dentata*, *Hypoglossum hypoglossoides* and *Phyllophora* spp. the thallus or fronds arise from a small discoid holdfasts. The spores of red algae are non-motile (Norton, 1992) and therefore entirely reliant on the hydrographic regime for dispersal. Norton (1992) reviewed dispersal by macroalgae and concluded that dispersal potential is highly variable, recruitment usually occurs on a much more local scale, typically within 10 m of the parent plant. Hence, it is expected that the red algal turf would normally rely on recruitment from local individuals and that recovery of populations via spore settlement, where adults are

removed, would be protracted.

Littler & Kauker (1984) suggest that crustose bases are an adaptation to resist grazing and desiccation whereas the fronds are adapted for higher primary productivity and reproduction. The basal crusts of *Corallina officinalis* are tougher than the upright fronds (requiring a pressure of 94 g/mm<sup>2</sup> to penetrate, compared to 43 g/mm<sup>2</sup> respectively). Regeneration of the basal crusts provides a more rapid route to recovery than recolonization. Experiments in the intertidal in southern California found that areas of *Corallina officinalis* scraped back to crusts recovered four times more rapidly than sterilised plots where the crusts were removed (Littler & Kauker, 1984). Resistant crustose bases therefore enable the turf of red algae and the crustose corallines to withstand and recover from physical disturbance and scour while preventing the establishment of other species (Mathieson & Burns, 1975; Dudgeon & Johnson, 1992). Where these remain after an impact they provide a significant recovery mechanism. Species without crustose bases may also reproduce vegetatively, for example *Dictyota dichotoma* can reproduce vegetatively by fragmentation (Tronholm *et al.*, 2010).

Some species found in this biotope, such as *Phyllophora* sp. exhibit annual growth and die back patterns as in this biotope where growth is removed annually by abrasion or water action leading to breakage (Molenaar & Breeman, 1994). Similarly *Plocamium cartilagineum* loses blades in winter in wave exposed conditions while the crustose bases survive and spread laterally (Kain, 1982, 1984, 1987). *Odonthalia dentata* also tends to lose blades each year with subsequent regrowth from thallus being enhanced each year due to tissue build-up (Kain, 1984).

Some temporal variation in abundance and biomass is therefore normal within this biotope. Macroalgae characterizing the biotope are either species with strategies to resist disturbance, e.g. growing back from more resistant crustose bases or short-lived species that can reproduce annually and maintain presence via germlings. *Dictyota dichotoma* is an annual plant in North Carolina plants reach maturity and die back within a year. Young germlings survive over the winter and maintain the population (Richardson, 1979). Maximum age estimates for species include *Odonthalia dentata* 5 or 9 years for a small proportion of the population (5 %) from Isle of Man (Kain, 1984). *Phycodrys rubens* in the Barents Sea, live to 4 years but 1 and 2 year olds are predominant (Schoschina, 1996).

Seasonality of reproduction varies between the red algal species within the site (Kain, 1982), so that timing of impacts will coincide with different phases of reproduction within species and may alter short-term recovery trajectories with effects on composition. In the Isle of Man, approximately 90% of *Plocamium cartilagineum*, *Callophyllis laciniata* and *Cryptopleura ramosa* plants were fertile in late summer but less than 10% in Spring, although some fertile plants were always present. In contrast *Odonthalia dentata* produced spores during the winter and late spring but was not fertile in the summer. *Phycodrys rubens* was present epiphytically and was fertile during the first half of the year (Kain, 1982). The encrusting coralline *Cruoria pellita* showed little seasonality (Kain, 1982).

Although ubiquitous in marine coastal systems little is understood about the taxonomy, biology and ecology of the characterizing crustose corallines (Littler & Littler, 2013). Coralline crust is a generic term that in UK biotopes refers to nongeniculate (crustose) species from the family Corallinacea that could include *Lithophyllum incrustans* which is noted to form thick crusts in tidepools, especially in the south west (Adey & Adey, 1973), *Lithothamnion* spp. and *Phymatolithon* spp. Due to the lack of evidence for species the assessments for encrusting corallines are generic, although species specific information is presented where available. A

number of papers by Edyvean & Ford (1984a & b; 1986; 1987) describe aspects of reproduction and growth of encrusting coralline, *Lithophyllum incrustans*. Studies by Edyvean & Forde (1987) in populations of *Lithophyllum incrustans* in Pembroke south-west Wales suggest that reproduction occurs on average early in the third year. Reproduction may be sexual or asexual. Populations release spores throughout the year but abundance varies seasonally, with the populations studied in Cullercoats Bay, and Lannacombe Bay (North East and South West England, respectively) producing less spores in the summer. Spore release is initiated by changes in temperature or salinity (see relevant pressure information) at low tide so that spore dispersal is restricted to within the tide pool enhancing local recruitment. Within subtidal biotopes this is not possible and recruitment success may be altered (although this may be compensated by avoidance of desiccation). Spore survival is extremely low with only a tiny proportion of spores eventually recruiting to the adult population (Edyvean & Ford, 1986). The spores are released from structures on the surface called conceptacles; these are formed annually and subsequently buried by the new layer of growth. Plants can be aged by counting the number of layers of conceptacles. Edyvean & Ford (1984) found that the age structure of populations sampled from Orkney (Scotland) Berwick (northern England) and Devon (England) were similar, mortality seemed highest in younger year classes with surviving individuals after the age of 10 years appear relatively long-lived (up to 30 years). In St Mary's Northumberland, the population was dominated by the age 6-7 year classes (Edyvean & Ford, 1984). Growth rates were highest in young plants measured at Pembroke (south-west Wales) with an approximate increase in diameter of plants of 24 mm in year class 0 and 155 mm in year 1 and slowing towards an annual average horizontal growth rate of 3mm/year (Edyvean & Ford, 1987).

Some repair of damaged encrusting coralline occurs through vegetative growth. 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. Recolonization by propagules is an important recovery mechanism. Airoldi (2000) observed that encrusting coralline algae recruited rapidly on to experimentally cleared subtidal rock surfaces in the Mediterranean Sea, reaching up to 68% cover in 2 months.

The associated species will vary in ability to respond to perturbations by inward and outward migration, repair damage to the body and to recolonize and therefore recovery rates will vary. The sponge *Halichondria panicea* and the anemone *Urticina felina* will readily repair damage to the body. For example, removal of tentacles by clipping does not alter behaviour or *Urticina felina* and the tentacle regenerates within a few days (Mercier *et al.*, 2011). *Urticina felina* internally broods young, providing a mechanism for recovery close to adults. However, recovery is likely to be slower in populations where nearby individuals do not exist. The large size, slow growth rate and evidence from aquarium populations suggest that *Urticina felina* is long lived. Dispersal ability is considered to be poor in the similar species *Urticina eques* (Solé-Cava *et al.* 1994). Adults can detach from the substratum and relocate but locomotive ability is very limited. Impacts that remove large proportions of the population over a wide area will effectively reduce the availability of colonists. However, the species colonized ex-HMS *Scylla* in the fourth year of the vessel being on the seabed (Sköld *et al.*, 2001).

*Echinus esculentus* may structure this biotope through grazing. As a group, echinoderms have a high fecundity; producing long lived planktonic larvae with high dispersal potential. However, recruitment in echinoderms is poorly understood, often sporadic and variable between locations and dependent on environmental conditions such as temperature, water quality and food availability. Recovery of populations may occur through repair of non-lethal damage, adult

migration into impacted areas or larval colonization. Lewis and Nichols (1979a) found that adults were able to colonize an artificial reef in small numbers within 3 months and the population steadily grew over the following year. Similarly, Nichols (1981; 1984) reported that a site where all sea urchins were removed in 1978 had returned by a subsequent survey in 1979 (although no abundance was given). Recruitment of urchins is sporadic or annual depending on locality and factors affecting larval pre-settlement and post-settlement survival. For example, the heart urchin *Echinocardium cordatum* recruitment only occurred in 3 years out of a 10 year period (Buchanan, 1967). Millport populations of *Echinus esculentus* showed annual recruitment, whereas few recruits were found in Plymouth populations during Nichols studies between 1980 and 1981 (Nichols, 1984). Bishop and Earll (1984) suggested that the population of *Echinus esculentus* at St Abbs had a high density and recruited regularly whereas the Skomer population was sparse, ageing and had probably not successfully recruited larvae in the previous 6 years. Also, *Echinus* is slow to mature and it would take up to 8 years for adult biomass to be restored (MES, 2010). It is possible for *Echinus* to recolonize areas from which it is lost quickly by migration, where there is a large resident population in the surrounding area, such as on rocky or hard substrata. However, recruitment is more variable, annual in some cases or prolonged in others. Therefore, as *Echinus esculentus* is widespread and abundant around the coasts of the UK, a local population is likely to recover via migration from the surrounding area, and a resilience of 'High' (<2 years) is suggested, however it should be noted that in isolated areas dependent on recruitment alone, resilience would likely be 'Medium' (2-10 years). In contrast, *Gibbula cineraria*, another grazer within the biotope, is a fast growing species with a short-lifespan (Schöne *et al.*, 2007) and pelagic dispersal stages (Underwood, 1972) and is considered to recover quickly (resilience is 'High' through migration from adjacent habitats and larval recolonization from any level of impact).

**Resilience assessment.** The biotope undergoes annual changes in algal biomass and structure with the scour tolerant and perennial species including crustose corallines and red algae with crustose bases (*Corallina officinalis* and *Plocamium cartilagineum*) and the associated long-lived species *Echinus esculentus*, *Halichondria panicea* and *Urticina felina* being the more stable elements. Where resistance is 'High' resilience is assessed as 'High' by default. Where resistance is 'Medium' then recovery is considered to be 'High' based on migration of mobile species, recolonization from the remaining population of annuals and perennial and vegetative growth and spread of perennial algae. Where resistance is 'Low' but crustose bases of red algae and parts of the Corallinacea remain then recovery is also assessed as 'High'. However where resistance is 'Low' or 'None' and the key characterizing crustose corallines and the crustose bases of *Corallina officinalis* and other holdfasts are likely to be removed then resilience is assessed as 'Medium'.

**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: Medium C: Medium

**High**

Q: High A: High C: High

**Not sensitive**

Q: High A: Medium C: Medium

The key characterizing red algal species found in this biotope have a range of geographic distributions with some having a 'southern distribution' with their range encompassing warmer waters and others having a 'northern' distribution. Temperature tolerances are therefore likely to vary between species so that long-term changes in temperature have the potential to shift the species composition of this biotope to one more suited to the prevailing thermal regime. This biotope occurs in the subtidal and is therefore protected from exposure to air so that the thermal regime is more stable and desiccation is not a factor. Examples of distribution and thermal tolerances tested in laboratory experiments are provided as evidence to support the sensitivity assessment. Populations can acclimate to prevailing conditions (Davison, 1991; Lohrmann *et al.*, 2004) which can alter tolerance thresholds and care should therefore be used when interpreting reported tolerances.

A number of the characterizing species found in the biotope such as *Plocamium cartilagineum*, *Cryptopleura ramosa*, *Callophyllis laciniata* and *Lithophyllum incrustans* are close to the northern edge of their reported distribution range in the UK (Kain, 1982; Guiry & Guiry, 2015). *Cryptopleura ramosa*, for example, is more common on southern shores of the UK (see MarLIN) and its distribution appears to be southern with worldwide records but none, from Canada, Scandinavia, Russia the Arctic or Antarctic (Guiry & Guiry, 2015) suggesting that it is likely to tolerate increased temperatures more successfully than decreased. The brown alga *Dictyota dichotoma* is also considered to be a warm-temperate species and is found throughout the NE Atlantic and Bermuda with the northern range extending to southern Norway and North Carolina (Van den Hoek, 1982; Tronholm *et al.*, 2010; Richardson, 1979). Based on the geographic range these species are considered more likely to tolerate chronic and acute increases in temperature at the pressure benchmark and a long-term change exceeding the pressure benchmark may increase habitat suitability. For example *Hypoglossum hypoglossoides* has recently expanded its range to Norway in response to warming temperatures (Husa, 2007). Tolerances within the southern group of red algae may vary, *Cryptopleura ramosa*, for example, is capable of surviving at 27 °C, while other characterizing species such as *Callophyllis laciniata*, *Plocamium cartilagineum*, died within 12 hours in seawater at 27 °C (Gessner, 1970). (It should be noted that this temperature increase exceeds that of the benchmark level).

Conversely, characterizing red algae that are at the southern edge of their range in the UK such as *Odonthalia dentata* (Kain, 1982) are potentially less tolerant of the pressure. *Odonthalia dentata*, in particular, has a marked northern distribution in the UK and is found in Scotland, northern England and north and west Ireland (Guiry & Guiry, 2015). Other species within the biotope such as *Phycodrys rubens* are distributed both north and south of the UK (Guiry & Guiry, 2015). *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). Both *Phycodrys rubens* and *Corallina officinalis* are likely to tolerate changes in temperature at the pressure benchmark. Experiments with isolates of *Phycodrys rubens* collected at different latitudes and the Baltic Sea/North Sea population group (Helgoland, Kiel, Barents Sea, the Kattegat, Ireland and Brittany) found that thermal tolerances were similar across the range (Voskoboinikov *et al.*, 1996). All isolates died at 20°C after 1-4 weeks and survived low temperatures (-1.5°C) without obvious damage (Voskoboinikov *et al.*, 1996). Isolates from southern populations were slightly more tolerant of warmer temperatures, growing well at 18°C when overall optimum growth for all samples was at 5-10°C (Voskoboinikov *et al.*, 1996). 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 the 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 while samples kept at lower temperatures 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.

Increases in temperature at the pressure benchmark may impact the associated grazing species. *Echinus esculentus* was recorded at temperatures between 0 - 18°C in the Limfjord, Denmark (Ursin 1960). Bishop (1985) noted that gametogenesis proceeded at temperatures between 11 - 19°C, although continued exposure to 19 °C destroyed synchronicity of gametogenesis between individuals. Embryos and larvae developed abnormally after up to 24hr at 15°C (Tyler & Young, 1998) but normally at the other temperatures tested (4, 7 and 11°C at 1 atmosphere). Bishop (1985) suggested that this species cannot tolerate high temperatures for prolonged periods due to increased respiration rate and resultant metabolic stress. *Echinus esculentus* is likely to have higher resistance to chronic long-term temperature change at the pressure benchmark but would probably be more intolerant of a short-term acute change (e.g. 5°C for 1 week) in temperature. The impact of a chronic change may be exacerbated or mitigated by the timing of the exposure with changes in summer having the potential to exceed thermal tolerances, although winter increases may also be stressful where the species has acclimated to cooler waters. Effects on larval supply and recruitment may also result from chronic and acute changes depending on site-specific temperatures.

Increases in temperature above 12°C induce spawning in *Gibbula cineraria* (Underwood, 1972; Clare, 1990). Individuals from a population from North East England spawned between late June and early September although females (but not males) could be induced to spawn in winter in response to a temperature increase but males could not (Clare, 1990). An acute increase in temperature that induced spawning in females but not males or that resulted in spawning and fertilization when other conditions were unsuitable would reduce recruitment success (Clare, 1990). This effect, at the duration of the pressure benchmark, is considered to be sub-lethal to the adult population.

**Sensitivity assessment.** The associated red algae and *Dictyoyta dichotoma* are considered likely to be tolerant of an acute or chronic change at the pressure benchmark, with most species, particularly those with a southern distribution, able to tolerate an acute increase in temperature greater than the pressure benchmark (Gessner, 1970). For the grazing species however, increases in temperature could disrupt reproduction. The effects would depend on the magnitude, duration and footprint of the activities that result in this pressure. Biotope resistance is assessed as '**High**' based on the red algae and resilience as '**High**' (by default). This biotope is therefore considered to be '**Not sensitive**' at the pressure benchmark. Sensitivity to longer-term, broad-scale perturbations such as increased temperatures from climate change could however be greater, based on degree of change, with direct effects on the composition of the red algae present or indirect effects arising from reduced grazing where reproduction success of *Gibbula cineraria* and *Echinus esculentus* is impacted.

**Temperature decrease  
(local)****High**

Q: High A: Medium C: Medium

**High**

Q: High A: High C: High

**Not sensitive**

Q: High A: Low C: Medium

The key characterizing red algal species found in this biotope have a range of geographic distributions with some having a 'southern distribution' with their range encompassing warmer waters and others having a 'northern' distribution. Temperature tolerances are therefore likely to vary between species so that long-term changes in temperature have the potential to shift the species composition of this biotope to one more suited to the prevailing thermal regime. Examples of distribution and thermal tolerances tested in laboratory experiments are provided as evidence to support the sensitivity assessment. Populations can acclimate to prevailing conditions (Davison, 1991; Lohrmann *et al.*, 2004) which can alter tolerance thresholds. During experimental attempts to adapt red algae to cold by maintaining them at -1°C to +1°C for several months, a drop in the lethal temperature tolerance of *Delesseria sanguinea* and a few other species was detected, in the order of 1 to 2°C (Gessner, 1970). Care should therefore be used when interpreting reported tolerances.

A number of the characterizing species found in the biotope such as *Plocamium cartilagineum*, *Cryptopleura ramosa*, *Callophyllis laciniata* and *Lithophyllum incrustans* are close to the northern edge of their reported distribution range in the UK (Kain, 1982, Guiry & Guiry, 2015). *Cryptopleura ramosa*, for example, is more common on southern shores of the UK (see MarLIN) and its distribution appears to be southern with worldwide records but none, from Canada, Scandinavia, Russia the Arctic or Antarctic (Guiry & Guiry, 2015) suggesting that it is likely to tolerate increased temperatures more successfully than decreased. The brown alga *Dictyota dichotoma* is also considered to be a warm-temperate species and is found throughout the NE Atlantic and Bermuda with the northern range extending to southern Norway and North Carolina (Van den Hoek, 1982; Tronholm *et al.*, 2010, Richardson, 1979) and may be sensitive to decreased temperatures. Richardson (1979) demonstrated that the young germling stage of *Dictyota dichotoma* can overwinter in North Carolina at the northern edge of its distribution where winter water temperatures are less than 10°C, providing a survival strategy. Edyvean & Forde (1984b) suggest that populations of *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). Tolerance of reductions in temperature will vary within this group. In experiments, *Cryptopleura ramosa* were partially or completely killed at 5 °C. Other species had a greater cold tolerance with *Callophyllis laciniata* and *Plocamium cartilagineum* surviving at -2 °C (Gessner, 1970).

Conversely, characterizing red algae that are at the southern edge of their range in the UK such as *Odonthalia dentata* (Kain, 1982) are potentially more tolerant of the pressure. *Odonthalia dentata* has a marked northern distribution in the UK and is found in Scotland, northern England and north and west Ireland (Guiry & Guiry, 2015). It is also found in Alaska, Svalbard and the Arctic (Guiry & Guiry, 2015), suggesting that a decrease in temperature at the pressure benchmark would not be detrimental to this species or reproduction.

Species that occur north and south of the UK are considered to be eurythermal and tolerant of a range of temperatures. Laboratory experiments have demonstrated that *Phycodryis rubens* has a greater tolerance of freezing temperatures than species with a southern distribution as mortality occurred only at temperatures of -3°C to -5°C (Gessner, 1970). Lüning (1990) reported that *Corallina officinalis* from Helgoland survived 0°C when exposed for one week, while New Zealand specimens were found to tolerate -4°C (Frazer *et al.*, 1988).

Although *Urticina felina* was apparently unaffected by the extremely cold winter of 1962/3 (Crisp, 1964), Gosse (1860) observed that ‘after the intense and protracted frost of February 1855, the shores of South Devon were strewn with dead and dying anemones, principally of this species’. Bearing in mind the equivocal observations from two cold winters, it is suggested that at least some individuals might be killed by extreme cold (exceeding the pressure benchmark).

*Echinus esculentus* was recorded at temperatures between 0 -18°C in the Limfjord, Denmark (Ursin, 1960). Embryos and larvae developed abnormally after up to 24 hr at 15°C but normally at the other temperatures tested (4, 7 and 11°C at 1 atmosphere) (Tyler & Young, 1998). This species is considered to be unaffected by decreases in temperature at the pressure benchmark

**Sensitivity assessment.** The characterizing red algae and *Dictyota dichotoma* are considered to be tolerant of an acute or chronic decrease in temperature at the pressure benchmark, with some species, particularly those with a northern distribution, able to tolerate an acute decrease in temperature greater than the pressure benchmark (Gessner, 1970). Changes in temperature may result in some shifts in community structure where thermal tolerances are exceeded and more sensitive species die but these changes are not considered to alter the overall character of the biotope. Resistance is therefore assessed as ‘High’ and resilience as ‘High’ (by default) based on the red algae. This biotope is therefore considered to be ‘Not sensitive’ at the pressure benchmark.

#### Salinity increase (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). The characterizing crustose corallines and *Corallina officinalis* are found in rockpools 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 *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).

Rietema (1991) found that *Phycodrys rubens* from the Baltic kept in a salinity regime grew and survived at all salinities from 33ppt to 7.5 ppt with maximum growth in the range from 23 down to 16.5 ppt, however *Phycodrys rubens* from the North Sea where salinities are higher grew and survived in a more limited range (33-16.5 ppt), with maximum growth between 33 and 23 ppt.

No evidence concerning the specific tolerance of the grazer *Echinus esculentus* was found, although Reid (1935) described its range as between 33.5 on the Norwegian Coast to 36.0 at Finisterre. Echinoderm larvae have a narrow range of salinity tolerance and develop abnormally and die if exposed to reduced or increased salinity. In general echinoderms are considered to be stenohaline species (Stickle & Diehl, 1987) although acclimation to euryhaline conditions with periodic hyposalinity has been observed in some species (Russell, 2013).

**Sensitivity assessment.** No evidence was found to assess the tolerance of the characterizing red algae to hypersalinity at the pressure benchmark. Although some increases in salinity may be

tolerated by the associated species present, this biotope is considered to be sensitive to a persistent increase in salinity to > 40 ppt (based on *Corallina officinalis* evidence and *Echinus esculentus*). Resistance is therefore assessed as 'Low' and recovery as 'Medium' (following restoration of usual salinity). Sensitivity is therefore assessed as 'Medium'.

### Salinity decrease (local)

**Low**

Q: High A: Low C: Medium

**Medium**

Q: High A: Low C: Medium

**Medium**

Q: High A: Low C: Medium

This biotope is recorded in full salinity habitats (Connor *et al.*, 2004). Salinity tolerances vary between species, *Urticina felina* the sponge *Halichondria panicea* and the red algae *Cryptopleura ramosa*, *Callithamnion* spp., *Hypoglossum hypoglossoides* occur in variable salinity on tide-swept biotopes (IR.MIR.KT.FilRVS) and would probably survive a reduction in salinity at the pressure benchmark. However other species within the biotope are likely to be more sensitive and a change at the pressure benchmark is considered likely to reduce species richness and result in the loss of characterizing species. Available evidence for sensitivities is described below.

A comparative study of salinity tolerances of macroalgae collected from North Zealand in the South Kattegat (Denmark) where salinity is 16 psu. Showed that species generally had a high tolerance (maintained more than half of photosynthetic capacity in short-term exposures (4 days) to salinities lower than 3.7 psu. However, tolerances varied between species with *Phyllophora pseudoceranooides* exhibiting greater tolerance than *Phycodrys rubens* which was the least tolerant species tested (Larsen & Sand-Jensen, 2006). However, *Phycodrys rubens* can still tolerate low salinities with populations in the Balttic Sea common where salinities are as low as 15 ppt (Van Oppen *et al.*, 1995) suggesting that local acclimation is possible.

Edyvean & Ford (1984b) suggest that populations of the crustose coralline *Lithophyllum incrustans* are affected by temperature changes and salinity and that temperature and salinity 'shocks' induce spawning but no information on thresholds were provided (Edyvean & Ford, 1984b). Populations of *Lithophyllum incrustans* were less stable in tide pools 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).

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 (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. *Corallina officinalis* and *Odonthalia dentata* do not penetrate far into the Kattegat where salinities are reduced (Pedersén & Snoeijs 2001).

No evidence concerning the specific tolerance of *Echinus esculentus* was found although Reid (1935) described its range as between 33.5 on the Norwegian Coast to 36.0 at Finisterre. Echinoderm larvae have a narrow range of salinity tolerance and develop abnormally and die if exposed to reduced or increased salinity (Russell, 2013). In general echinoderms are considered to be stenohaline species (Stickle & Diehl, 1987) although acclimation to euryhaline conditions with periodic hyposalinity has been observed in some species (Russell, 2013). Populations in the sublittoral fringe probably encounter reduced salinity due to low water and freshwater runoff or

heavy rain and may tolerate low salinity for short periods.

The anemone *Urticina felina* occurs in estuaries e.g. the Thames estuary at Mucking and the River Blackwater estuary (Davis, 1967). Braber and Borghouts (1977) found that *Urticina* (as *Tealia*) *felina* penetrated to about the 11 ppt Chlorinity isohaline (corresponding to about 20 psu based on conversion rates) at mid tide during average water discharge in the Westerschelde estuary suggesting that it would be tolerant of reduced salinity conditions. Intertidal and rock pool individuals will also be subject to variations in salinity because of precipitation on the shore; albeit for short periods on the lower shore. Therefore, the species seems to have a high tolerance to reduction in salinity but may have to retract tentacles and suffer reduced opportunity to feed.

**Sensitivity assessment.** The available evidence illustrates that responses to this pressure will vary between species and that a change at the pressure benchmark is likely to alter the composition of the red algal turf that characterizes the biotope and may alter the biomass and density of more tolerant species. Resistance is therefore assessed as 'Low' (loss of 25-75% of individuals). Resilience (following the removal of this pressure) is assessed as 'Medium' (2-10 years) based on loss of characterizing coralline crusts and sensitivity is therefore assessed as 'Medium'.

#### Water flow (tidal current) changes (local)

High

Q: High A: Low C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: Low C: High

This biotope occurs across a range of flow speeds, from moderately strong (0.5-1.5 m/s) to areas where water flow is negligible (Connor *et al.*, 2004). As water velocity increases foliose macroalgae can flex and reconfigure to reduce the size of the alga when aligned with the direction of flow, this minimises drag and hence the risk of dislodgement (Boller & Carrington, 2007). These characteristics allow these species to persist in areas that experience a range of flow speeds. Biogenic habitat structures, including the fronds of algae, reduce the effects of water flows on individuals by slowing and disrupting flow. Boller and Carrington (2006) found that the canopy created by a turf of *Chondrus crispus* reduced drag forces on individual plants by 15-65%. The compact, turf forming growth of the algal species characterizing this biotope will therefore reduce water flow and the risk of displacement through turbulence and friction.

The coralline crusts characterizing this biotope are securely attached and as these are flat they are subject to little or no drag compared to upright growth forms of algae. Colonies of *Lithophyllum incrustans* appear to thrive in conditions exposed to strong water movement (Irvine & Chamberlain, 1994). The suspension feeders within the biotope will also benefit from high water flows bringing food.

The anemone *Urticina felina* favours areas with strong tidal currents (Holme & Wilson, 1985; Migné & Davoult, 1997) although it is also found in calmer and sheltered areas as well as deep water. Records from the MNCR database were used as a proxy indicator of the resistance to water flow changes by this species by Tillin & Tyler-Walters (2014). The records indicate the water flow categories for biotopes characterized by *Urticina felina* range from very strong to very weak (negligible) (negligible to >3m/s) suggesting that a change in the maximum water flow experienced by mid-range populations for the periods of peak spring tide flow would not have negative effects (Tillin & Tyler-Walters, 2014).

Records from the MNCR database were used as a proxy indicator of the resistance to wave height changes by *Echinus esculentus* (Tillin & Tyler-Walters, 2014). The latest version of the JNCC

National Biodiversity Database was used as the source of the MNCR data. *Echinus esculentus* was recorded in biotopes from moderately strong (0.5-1.5m/s) to very weak (negligible) tidal streams, predominately in rock, mixed or very coarse sediment. *Echinus esculentus* move up the shore towards shallower waters when displaced, which is probably adaptation to displacement to deeper waters by wave action (Lewis & Nichols, 1979). Therefore, increased water flow is unlikely to kill individuals but may displace the population. However, once conditions return to prior condition, the species would probably migrate back from the surrounding area.

Scour is a key factor structuring this biotope (Connor *et al.*, 2004), changes in the flow may increase or decrease sediment transport and associated scour. Changes at the pressure benchmark are only likely to affect examples of this biotope that occur in sheltered areas with lower levels of water movement. Reductions in flow in areas where currents are weak may lead to increased deposition of silts and alter the character of the biotope, whereas an increase in water flow at the pressure benchmark may re-suspend and remove sand particles which are less cohesive than mud particles. The level of impact will depend on site specific hydrodynamic and sediment conditions. Some periodic movement of sediments and changes in coverage is part of the natural temporal variation and periodic disturbances from storms may be more important than water flow in maintaining the character of the biotope, particularly in sheltered areas. At the level of the pressure benchmark a change in water flow is considered unlikely to affect the level of wave surge and boulder scour that maintain the habitat.

**Sensitivity assessment.** As the biotope can occur in a range of flow speeds, resistance of the biotope to changes in water flow is assessed as 'High' and resilience as 'High' (by default) so that the biotope is assessed as 'Not sensitive'.

#### Emergence regime 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

Changes in emergence are not relevant to this biotope (group) which is restricted to fully subtidal habitats.

#### Wave exposure changes (local)

High

Q: High A: Low C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: Low C: High

This biotope is recorded from locations that are judged to range from extremely exposed, very exposed, or exposed (Connor *et al.*, 2004), while Dommasnes (1969) recorded turfs from very wave sheltered areas in Norway. The degree of wave exposure influences wave height. 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. As water movement from wave action increases, foliose macroalgae can flex and reconfigure to reduce the size of the alga when aligned with the direction of flow, this minimises drag and hence decreases the risk of breakage and dislodgement (Boller & Carrington, 2007). These characteristics allow these species to persist in areas that experience a range of flow speeds resulting from wave action. The crustose corallines associated with this biotope have a flat growth form and are unlikely to be dislodged by increased wave action. Colonies of *Lithophyllum incrustans* appear to thrive in conditions exposed to strong water movement (Irvine & Chamberlain, 1994).

A decrease in wave exposure at the pressure benchmark is unlikely to affect the red algae directly. Decreases greater than the pressure benchmark that lead to reductions in boulder instability, abrasion and scour may lead to changes in the assemblage as species more characteristic of areas with less wave exposure are likely to colonize.

The available evidence suggests that associated species, including grazers occur across a range of wave exposures and are unlikely to be affected by a change in wave exposure at the pressure benchmark. Areas with high water velocities provide food to suspension feeders within the biotope such as sponges and anemones. Records from the MNCR database were used as a proxy indicator of the resistance to wave height changes by *Urticina felina*. The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The records indicate the wave exposure categories for *biotopes* characterized by members of this ecological group as extremely sheltered; very sheltered; sheltered; moderately exposed; exposed; very exposed (Tillin & Tyler-Walters, 2014). *Echinus esculentus* can also occur within a range of wave exposure categories (Tillin & Tyler-Walters, 2014). An increase or decrease in wave height at the pressure benchmark is therefore considered to fall within the natural range of conditions experienced by this species. *Echinus esculentus* exhibit positive geotaxis and move up the shore towards shallower waters when displaced, which is probably adaptation to displacement to deeper waters by wave action (Lewis & Nichols, 1979).

*Gibbula cineraria* also appear to tolerate a range of wave exposures from exposed sites to those that are very sheltered (Frid & Fordham, 1994). The morphology of the shell varies according to wave exposure allowing individuals to adapt to different conditions in the habitat in which the larvae settle (Frid & Fordham, 1994). *Gibbula cineraria* is, however, absent from areas with very strong and turbulent flow

**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
<b>Transition elements &amp; organo-metal contamination</b>	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. 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.



Uptake of heavy metals from solution by seaweed is influenced by factors such as light, algal nitrogen content, frond age, length of emersion, temperature, salinity, season of the year and presence of other pollutants in the surrounding water (see Lobban & Harrison, 1997) and consequently seaweeds may not accurately reflect metal concentrations in the surrounding water. The order of metal toxicity to algae varies with the algal species and the experimental conditions, but generally the order is Hg>Cu>Cd>Ag>Pb>Zn (Rice *et al.*, 1973; Rai *et al.*, 1981), however insufficient information was available to comment further on the particular intolerance of algal species within the biotope. Kinne (1984) reported developmental disturbances in *Echinus esculentus* exposed to waters containing 25 µg / l of copper (Cu) and reduced species viability would result in the long-term as the species fail to successfully recruit. The information available is patchy but there would appear to be some intolerance of species within the biotope to heavy metals.

### Hydrocarbon & PAH contamination

Not Assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

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

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).

O'Brien & Dixon (1976) concluded that red algae were the most sensitive group of algae to hydrocarbon or dispersant contamination, possibly attributable to the susceptibility of the photosynthetic pigment phycoerythrin to chemical damage. Following a series of laboratory and field experiments Grandy (1984) reported *Delesseria sanguinea*, *Cryptopleura ramosa*, *Phycodrys rubens* and *Plocamium cartilagineum* to be sensitive to oil/dispersant mixtures; *Cryptopleura ramosa* and *Plocamium cartilagineum* were the most sensitive and *Phycodrys rubens* the least sensitive. In toxicity experiments, Smith (1968) found *Delesseria sanguinea* to be particularly intolerant of the oil dispersant BP 1002; 10 ppm of BP 1002 was lethal to the species. Heavy mortality of *Delesseria sanguinea* was also observed down to a depth of 12 m after the *Torrey Canyon* oil spill (Drew *et al.*, 1967). However, experience during the *Torrey Canyon* oil spill seems to be exceptional. As after the *Esso Bernicia* spill in 1978 in the Sullom Voe and heavy use of dispersants on significant quantities of oil, practically no damage to shallow (< 5 m) red algae could be found in Martins Haven (K. Hiscock, pers. comm.). Following the *Sea Empress* oil spill the most dramatic effect on the seaweeds was the marked bleaching of the encrusting coralline algae *Lithothamnium incrustans* and *Phymatolithon purpureum*. *Corallina officinalis*, *Chondrus crispus* and *Mastocarpus stellatus* also showed signs of bleaching. The encrusting corallines, however, recovered quickly, suggesting that

the damage had been restricted to the surface layers (Y. Chamberlain, pers. comm. to Crump *et al.*, 1999). At the depth at which this biotope occurs, only in the most severe conditions would damage probably occur to the characterizing species.

### 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.

O'Brien & Dixon (1976) report that red algae are effective indicators of detergent damage since they undergo colour changes when exposed to relatively low concentrations. Smith (1968) reported that 10 ppm of the oil dispersive detergent BP 1002 killed the majority of specimens in 24hrs in toxicity tests. However, the effects take several days to manifest; when killed the algae turn bright orange. Smith (1968) also demonstrated that 0.5 - 1ppm of the detergent BP1002 resulted in developmental abnormalities in echinopluteus larvae of *Echinus esculentus*. *Echinus esculentus* populations in the vicinity of an oil terminal in La Coruna Bay, Spain, showed developmental abnormalities in the skeleton. Hoare & Hiscock (1974) reported that red algae (e.g. *Lithothamnium* spp., *Corallina officinalis*, *Polyides rotunda*, *Dilsea carnosa*, *Rhodomenia palmata* and *Desmarestia aculeata*), echinoderms, Polyzoa and amphipod crustaceans appeared to be particularly intolerant of the reduction in water quality associated with the effluent discharged (containing free halogens, HCL & H<sub>2</sub>SO<sub>4</sub>) from a bromine extraction works into Amlwch Bay, Anglesey. Red algal species and the urchin *Echinus esculentus* are likely to be affected by synthetic chemicals.

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.

### 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

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

Specific information concerning oxygen consumption and reduced oxygen tolerances were not found for the key characterizing species within the biotope. This pressure is not assessed due to lack of evidence.

### Nutrient enrichment

High

Q: High A: Low C: High

High

Q: High A: High C: Medium

Not sensitive

Q: High A: Low C: High

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 characterizing *Corallina officinalis* has 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, Arévalo *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. *Corallina elongata* and the crusting coralline *Lithophyllum incrustans* were present at sites dominated by *Ulva* spp. in the Mediterranean exposed to high levels of nutrient enrichment from domestic sewage (Arévalo *et al.*, 2007). Increased eutrophication of the Skagerrak has been linked to an increase in abundance of the characterizing species *Phycodrys rubens*, increases in this species have also been observed with local eutrophication in shallow bays in the Baltic (Pedersén & Snoeijs 2001), suggesting this species is tolerant of some enrichment.

Grazers in the biotope may benefit from increased availability of food resources, due to enhanced growth, and high levels of grazing may reduce the effects of eutrophication. Atalah & Crowe (2010) added nutrients to rockpools in controlled experiments. 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. The invertebrates present were mostly *Patella ulyssiponensis*, the wrinkle *Littorina littorea* and the flat top shell *Gibbula umbilicalis*. 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. A grazer and nutrient addition treatment was also applied where grazers were removed manually from pools and a 1 m strip bordering the pools. 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 nutrients had no significant effect on the cover of crustose coralline algae or the red turfing algae. There was a significant interactive effect of grazing and nutrients however on the cover of crustose coralline algae. Pair-wise comparisons showed that cover of crustose coralline algae was significantly reduced where nutrients were added only under reduced grazing conditions, with an absolute decrease of 44% ( $\pm 8.0$  S.E.) relative to the controls ( $P < 0.05$ ). Grazers limit the effects of nutrient enrichment and in the absence of *Gibbula cineraria*, *Echinus esculentus* and other grazers significant changes in the structure of the algal assemblage could emerge following eutrophication. However, the high levels of scour and abrasion in this biotope would prevent permanent colonization by larger perennial species and ephemeral algae would be likely to be displaced by space-occupying red algae following disturbance and the creation of gaps.

**Sensitivity assessment.** The pressure benchmark is relatively protective and may represent a reduced level of nutrient enrichment in previously polluted areas and may limit the growth of ephemeral green algae. Due to the tolerance of high levels of nutrient input demonstrated generally by encrusting corallines and red algal turfs, e.g. Belgrove *et al.*, (2010) and Atalah & Crowe, (2010), resistance to this pressure is assessed as 'High' and resilience as 'High' so that the biotope is assessed as 'Not sensitive'.

## Organic enrichment

High

Q: High A: Medium C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: Medium C: High

As 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 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). As turfs of red algae can trap large amounts of sediment the red algae are not considered sensitive to the sedimentation element of this pressure. Within trapped sediments associated species and deposit feeders would be able to consume inputs of organic matter.

The animals found within the biotope may be able to utilise the input of organic matter as food, or are likely to be tolerant of inputs at the benchmark level. In a recent review, assigning species to groups based on tolerances to organic pollution, the anemone *Urticina felina* and the sponge *Halichondria panicea* were assigned to AMBI Group II described as 'species indifferent to enrichment, always present in low densities with non-significant variations with time, from initial state, to slight unbalance' (Gittenberger & van Loon, 2011). Lawrence (1975) reported that sea urchins had persisted over 13 years on barren grounds near sewage outfalls, presumably feeding on dissolved organic material, detritus, plankton and microalgae, although individuals died at an early age. The ability to absorb dissolved organic material was suggested by Comely and Ansell (1988).

**Sensitivity assessment.** Based on resistance to sedimentation, exposure to wave action, and the dominance of red algal 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
<b>Physical loss (to land or freshwater habitat)</b>	<b>None</b> Q: High A: High C: High	<b>Very Low</b> Q: High A: High C: High	<b>High</b> 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.

	Low	Very Low	High
<b>Physical change (to another seabed type)</b>	<b>Low</b> Q: High A: High C: High	<b>Very Low</b> Q: High A: Low C: High	<b>High</b> Q: High A: Low C: High

In the absence of hard substratum crustose corallines can propagate as free-living rhodolith nodules and can form extensive subtidal habitats (Littler & Littler, 2013). However, these biogenic reefs are not analogous to this habitat type. The loss of hard substratum would alter the habitat and sediments would be unsuitable for the crustose corallines and other attached algae that characterize this biotope. Other associated species such as sponges would also be lost as these are associated with rock habitats.

Artificial hard substratum may also differ in character from natural hard substratum, so that replacement of natural surfaces with artificial may lead to changes in the biotope through changes in species composition, richness and diversity (Green *et al.*, 2012; Firth *et al.*, 2013) or the presence of non-native species (Bulleri & Airoidi, 2005). Many species have specific preferences for substratum type. *Corallina officinalis* shows optimal settlement on finely rough artificial substrata (0.5 - 1 mm 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 only fronds can grow from bases attached to smooth surfaces (Wiedeman pers comm. Previous MarLIN review). 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) indicating species specific optimal habitats.

**Sensitivity assessment.** Based on the loss of suitable habitat, resistance is assessed as 'None' recovery is assessed as 'Very Low' as the change at the pressure benchmark is permanent. Sensitivity is therefore 'High'.

	Not relevant (NR)	Not relevant (NR)	Not relevant (NR)
<b>Physical change (to another sediment type)</b>	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR

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

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: Low C: Medium

High

Q: High A: Low C: Medium

Low

Q: High A: Low C: Medium

The species characterizing this biotope occur on the rock and therefore have no protection from abrasion at the surface. Little direct evidence was found to assess this pressure and evidence from intertidal studies on trampling on algal turfs has been used as a proxy. 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 fucoid canopy (Hawkins & 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. Littler and 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).

Schiel & Taylor (1999) reported the death of encrusting corallines one month after trampling due

to removal of their protective canopy of fucoids by trampling (10 -200 tramples where one trample equals one transect walked by one person). A higher proportion of corallines died back in spring treatments presumably due to the higher levels of desiccation stress expected at this time of year. However, encrusting corallines increased within the following year and cover returned to control levels within 21 months (Schiel & Taylor, 1999). Mechanical abrasion from scuba divers was also reported to impact encrusting corallines, with cover of *Lithophyllum stictaeforme* greater in areas where diving was forbidden than visited areas (abundance, 6.36 vs 1.4; it is presumed this refers to proportion of cover, although this is not clear from the text, Guarinieri *et al.*, 2012).

Dethier (1994) experimentally manipulated surface abrasion on a range of encrusting algae including *Lithophyllum impressum*. Crusts were brushed with either a nylon or steel brush for 1 minute a month for 24 months. Unbrushed controls grew by approximately 50% where the cover of nylon brushed crusts and steel brushed crusts decreased by approximately 25% and 40% respectively (interpreted from figures in Dethier, 1994). In laboratory tests on chips of *Lithophyllum impressum* brushing with a steel brush for 1 minute once a week for 3 weeks, resulted in no cover loss of two samples while a third 'thinned and declined' (Dethier, 1994).

In a recent review, assigning species to groups based on tolerances to bottom disturbance from fisheries, the anemone *Urticina felina* and the sponge *Halichondria panicea* were assigned to AMBI Fisheries Group II, described as 'species sensitive to fisheries in which the bottom is disturbed, but their populations recover relatively quickly' (Gittenberger & van Loon, 2011).

MacDonald *et al.*, (1996) assessed benthic species sensitivity to fishing disturbance by 'scoring' each species ability to withstand the physical impact of a single fishing disturbance and recovery potential assuming no further fishing disturbance occurred. These authors classified the slow growing epifaunal species *Echinus esculentus* as being 'very fragile' and having 'moderate' recovery potential, based on life history characteristics. Kaiser *et al.* (2000) reported that *Echinus esculentus* were less abundant in areas subject to high trawling disturbance in the Irish Sea. This species was reported to suffer badly as a result of impact with passing scallop or queen scallop dredges (Bradshaw *et al.* 2000; Hall-Spencer & Moore, 2000a).

**Sensitivity assessment.** The impact of surface abrasion will depend on the footprint, duration and magnitude of the pressure. Based on evidence from intertidal step experiments and the relative robustness of encrusting corallines, *Corallina officinalis* turf and associated red algal 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).. Resistance is therefore assessed as 'Low' and recovery as 'Medium' so that the sensitivity of the biotope defined by this species is assessed as 'Medium'. Based on epifaunal position, size and fragility and the available evidence *Echinus esculentus* is assessed as having 'Low' resistance to abrasion. Resilience is assessed as 'High' and therefore sensitivity is assessed as 'Low'.

**Penetration or disturbance of the substratum subsurface**

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

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

**Changes in suspended solids (water clarity)****High**

Q: High A: Low C: High

**High**

Q: High A: High C: High

**Not sensitive**

Q: High A: Low C: Medium

This biotope occurs in boulder scoured and wave surged habitats and it is likely, depending on local sediment supply, that the biotope is exposed to chronic or intermittent episodes of high-levels of suspended solids as local sediments are re-mobilised and transported. A significant increase in suspended solids may result in smothering (see siltation pressures) where these are deposited. Based on Cole *et al.* (1999) and Devlin *et al.* (2008) this biotope is considered to experience intermediate turbidity (10-100 mg/l) based on UK TAG (2014). An increase at the pressure benchmark refers to a change to medium turbidity (100-300 mg/l) and a decrease is assessed as a change to clear (<10 mg/l) based on UK TAG (2014).

In general, this biotope is considered to be relatively tolerant of high levels of suspended solids as increases in the cover of sediment trapping, turf forming algae at the expense of canopy forming species has been observed worldwide, in temperate systems, linked to increased suspended solids resulting from human activities (Airoldi, 2003). 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 as wave action removes sediments.

Increased suspended sediments may also result in increased scour, which may adversely affect foliose red algae, and interfere with settling spores and recruitment of the factor is coincident with their major reproductive period. Tolhurst *et al.* (2007) found that *Ulva intestinalis* germlings kept in tanks and exposed to 100 mg/l of suspended sediment showed reduced growth. Similarly, Hyslop & Davies (1998) found that the green alga *Ulva lactuca* lost weight when kept in flasks with 1 g/l of colliery waste that was shaken for 1 hour every day for 8 days. The experimental solids level, however, exceeds the pressure benchmark and *Ulva* are very thin species and are probably more susceptible to scour damage than red algae. 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.

Increases in suspended sediments may impact filter feeders such as *Halichondria panicea* within the biotope by reducing feeding efficiency, however, an increase in organic solids would supply more food. *Urticina felina* and *Halichondria panicea* are found in highly turbid areas associated with biotopes such as CR.MCR.SfR.Pol (Connor *et al.*, 2004) and are therefore considered to be unaffected by an increase in turbidity at the benchmark.

Moore (1977) suggested that *Echinus esculentus* was unaffected by turbid conditions. Echinoderm pedicellariae keep the test clear of settling larvae, spores and presumably sediment particles. *Echinus esculentus* is known to ingest sediment (Comely & Ansell, 1988) possibly to extract microalgae. Therefore, an increase in suspended solids may not kill this species but is likely to interfere with feeding and additional scour may reduce larval settlement.

A reduction in suspended solids that resulted in reduced scour may increase the abundance of foliose red algae and growth rates and result in a change in species composition as species less tolerant of scour colonized the biotope. However, where the levels of boulder scour that structure the biotope are unaffected it is judged that these changes would not be significant within a year. Although accumulated sediment within the red algal turf is likely to increase the species diversity of the epiphytic fauna, in very wave exposed locations sediment accumulation in the habitat is likely to be minimal. A reduction in suspended solids will probably reduce food availability for filter



feeding species in the biotope (where the solids are organic), although effects are not likely to be lethal over the course of a year.

The biotope occurs in shallow waters where light attenuation due to increases in turbidity is probably low. Red algae and coralline algae especially are known to be shade tolerant and are common components of the understory on seaweed dominated shores. An increase or decrease in light intensity is unlikely to adversely affect the biotope as plants can acclimate to different light levels.

**Sensitivity assessment.** Overall biotope resistance is assessed as 'Medium' to an increase in suspended solids, as increased scour may reduce the biomass of red algae and may remove some individuals or species that are more sensitive. However, the encrusting corallines and some red algae turf is considered likely to survive. Resilience is categorised as 'High' as some adults are likely to remain *in situ* from which recruitment can occur. The biotope is considered to be 'Not sensitive' to decreased suspended solids where scour and abrasion are unaffected. This biotope is considered to be 'Not sensitive' to a change in suspended solids, where levels of scour are unaffected. A reduction in scour may allow less scour tolerant species and those adapted to higher light levels, such as kelps, to colonize the biotope. Resistance to a decrease in suspended solids, accompanied by a significant reduction in scour is assessed as 'Medium' as space pre-emption by red algae is likely to limit colonization. Resilience (following a return to previous habitat conditions) is assessed as 'High'. Sensitivity is therefore assessed as 'Low'.

#### Smothering and siltation rate changes (light)

High

Q: High A: Medium C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: Medium C: High

Increased abundance of algal turfs worldwide has been linked to sediment perturbations although not all the pathways and mechanisms of these effects are clear (see review by Airoidi, 2003). However, 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 (Airoidi, 2003). *Corallina officinalis* (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 and other characterizing species in the biotope 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). Algae with tough thalli such as *Phyllophora pseudoceranoides* are more resistant to sedimentation and scour (Pedersén & Snoeijs 2001). In a review of the effects of sedimentation on rocky coast assemblages, Airoidi (2003) outlined the evidence for the sensitivity of encrusting 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).

In an experimental study, Balata *et al.* (2007) enhanced sedimentation on experimental plots in the Mediterranean (close to Tuscany) by adding 400 g of fine sediment every 45 days on plots of 400 cm<sup>2</sup> for 1 year. Nearby sites with higher and lower levels of sedimentation were assessed as control plots. Some clear trends were observed. *Dictyota dichotoma* was more abundant at sites with lower sedimentation (mean 2 and 6% of cover) and present in lower abundances (<1 %) at sites where sediments were added and at sites with naturally high sediment loads (Balata *et al.*, 2007). Foliose algae, in general, were present in much greater abundances in areas with low sedimentation (mean cover of approximately 13% and 19%) and much reduced at experimental sites and those with high natural sedimentation (mean cover of approximately 2-3 %). Crustose corallines declined at medium and high levels of sedimentation but were still major space occupiers (100% cover). Some species of filamentous algae increased where sediment loads were naturally high or experimentally enhanced (Balata *et al.*, 2007). The experiment relates to chronic low levels of sedimentation rather than a single acute event, as in the pressure benchmark, however the trends observed are considered to have some relevance to the pressure assessment. Foliose algae within the biotope are likely to be more sensitive to sedimentation than the characterizing encrusting corallines, however the presence of these, including *Dictyota dichotoma* in sand scoured biotopes suggest these have some tolerance of sedimentation and associated scour.

Communities dominated by the anemone *Urticina felina* were described on tide swept seabed, exposed to high levels of suspended sediment, sediment scour and to periodic smothering by thin layers of sand, up to ca 5cm in the central English Channel (Home & Wilson, 1985). *Urticina felina* is abundant in the sediment-scoured, silty rock communities CR.HCR.XFa.FluCoAs and CR.MCR.EcCr.UrtScr (Connor *et al.* 2004). Laboratory experiments have shown that another anemone *Sagartiogeton laceratus* is able to survive under sediments for 16 days and to be capable of re-emerging under shallow (2cm) burial (Last *et al.*, 2011). The percentage mortality increased with both depth and increasingly finer sediment fraction. Bijkerk (1988, results cited from Essink (1999) indicated that the maximal overburden through which the anemone *Sagartia elegans* could migrate was <10cm in sand. No further information was available on the rates of survivorship or the time taken to reach the surface. Cooke (1957, cited in Cranmer, 1985) stated that echinoids 'dislike mud', possible because of fine substratum affecting their respiratory capability (Dyer *et al.*, 1983). However, the associated urchin species *Echinus esculentus* is likely to be able to tolerate small quantities of sediment deposition (MES, 2010). Comely and Ansell (1988) recorded large *Echinus esculentus* from kelp beds on the west coast of Scotland in which the substratum was seasonally covered with 'high levels' of silt. Last *et al.* (2011) found that a smaller epifaunal urchin *Psammechinus miliaris* is moderately tolerant of shorter term (12 days) burial events, with less than 25% mortality of all buried specimens. Survivorship was partly due to the re-emergence of many specimens, even from depths of up to 7cm, particularly when buried under coarse sediment. After 12 days of burial, mortality in the specimens that remained buried was high. Percentage mortality increased with progressively finer sediment fractions.

**Sensitivity assessment.** Based on the biotope exposure to wave and water flow which will remobilise sediments and remove these, the growth form of the characterizing foliose red algae and the presence of these algae and *Urticina felina* in biotopes subject to sedimentation and scour (including the assessed biotope), biotope resistance to this pressure, at the benchmark, is assessed as 'High', resilience is assessed as 'High' (by default) and the biotope is considered to be

'Not sensitive'. The assessment considers that sediments are rapidly removed from the biotope and that the scour tolerance of the red algae and other species would prevent significant mortalities although some damage and abrasion may occur. However, if the deposit remained in place; i.e. due to the scale of the pressure or where biotopes were sheltered, or only seasonally subject to water movements or where water flows and wave action were reduced e.g. by the presence of tidal barrages, then resistance would be lower and sensitivity would be greater.

### Smothering and siltation rate changes (heavy)

**Low**

Q: High A: Low C: Medium

**High**

Q: Low A: NR C: NR

**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. Complete burial of algal turf and encrusting corallines and associated animals would occur. Removal of the sediments by wave action and tidal currents would result in considerable scour. The effect of this pressure will be mediated by the length of exposure to the deposit.

No evidence was found for the length of time *Echinus esculentus* could survive being buried under 30cm of sediment. In areas of high water flow, dispersion of fine sediments may be rapid and this will mitigate the magnitude of this pressure by reducing the time exposed and the depth of overburden that the species must crawl through

**Sensitivity assessment.** Resistance is assessed as 'Medium-Low' as the impact on the characterizing and associated red algal species and *Urticina felina* could be significant but may be mitigated by rapid removal. Resilience is assessed as 'High' based on vegetative re-growth from the scour-tolerant surviving bases of the characterizing species. Biotope sensitivity is therefore assessed as 'Low'. Resistance of *Echinus esculentus* to this pressure was assessed as 'None' by Tillin & Tyler-Walters (2014) due to the depth of overburden and the predicted low level of vertical migration. Resilience was assessed as 'Medium' (2-10 years) and sensitivity is therefore assessed as 'Medium'. Sensitivity may be lower where the footprint of the deposit is small and migration of adults into the habitat from adjacent populations results in rapid recovery.

### 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: Medium C: Medium

**High**

Q: High A: High C: High

**Not sensitive**

Q: High A: Medium C: Medium

The red algae are generally flexible in terms of light requirements and can acclimate to different levels of light intensity and quality. Coralline crusts and *Corallina officinalis* are shade tolerant algae, often occurring under a macroalgal canopy that reduces light penetration. 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). Similarly *Plocamium cartilagineum* grows in shaded conditions beneath laminarian canopies: where irradiance is greater, growth is lower and it appears that light levels of 0.5 mmol/m<sup>2</sup>/s are inhibitory (Kain, 1987). In areas of higher light levels, the fronds and bases 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.

**Sensitivity assessment.** As the key structuring and characterizing red algae species colonize a broad range of light environments, from intertidal to deeper sub tidal and shaded understorey habitats, the biotope is considered to have 'High' resistance and, by default, 'High' resilience and therefore is 'Not sensitive' to this pressure.

**Barrier to species movement****High**

Q: NR 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 red algal turfs 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. 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

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

**Introduction or spread of invasive non-indigenous species**

High

Q: High A: Low C: Low

High

Q: High A: High C: High

Not sensitive

Q: High A: Low C: Low

The high levels of scour in this biotope will limit establishment of all but scour resistant invasive non-indigenous species (INIS) from this biotope and no direct evidence was found for effects of INIS on this biotope. A number of invasive red algae have been recorded in the UK, from reported habitat preferences *Bonnemaisonia hamifera* does not appear to be present in scoured environments although the harpoon weed, *Asparagopsis armata* is found in sandy pools (Guiry & Guiry, 2015). In North America *Grateloupia turuturu* is a major competitor of *Chondrus crispus*, although *Grateloupia turuturu* is present in the UK, this large foliose species may not be able to colonize this scoured biotope.

The invasive red algae *Lophocladia lallemandi* that grows on *Dictyota dichotoma* in Mallorcan coastal waters results in an increase in antioxidant biomarkers indicating stress and cellular damage that could lead to increased mortality (Tejada & Sureda, 2014). This species is not currently present in the UK but illustrates a potential effect on INIS on native species.

**Sensitivity assessment.** As sand scouring of this biotope limits establishment of all but robust species, resistance to INIS is assessed as 'High' and resilience as 'High' (by default) so that the biotope is considered to be 'Not sensitive'.

**Introduction of microbial pathogens**

High

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 that microbial pathogens cause high levels of disease or mortality in this biotope. 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 corallines, again in the tropic (Littler *et al.*, 2007). No evidence was found that these are impacting temperate coralline habitats.

Extracts of some red algae show antimicrobial, antiviral or antifungal properties providing some protection from pathogens. For example extracts of *Odonthalia dentata* reduced the rate of colony extension in *Microsporium canis* and *Trichophyton verrucosum*, with seasonal variations in the levels of inhibitory activity (Tariq, 1991). Similarly *Corallina officinalis*, has been demonstrated to produce antibacterial substances (Taskin *et al.*, 2007). Extracts of *Dictyota dichotoma* have antibiotic properties (Hornsey & Hide, 1974) and antiviral properties (Rabanal *et al.*, 2014).

It is likely that populations within this biotope suffer some low-levels of infection of microbial pathogens and parasites. Several coralline and non-coralline species are epiphytic on *Corallina officinalis*. Irvine & Chamberlain (1994) cite tissue destruction caused by *Titanoderma corallinae*. Other specific examples include the red algal hemiparasite *Gonimophyllum buffhamii*, that occurs occasionally on subtidal *Cryptopleura ramosa* on southern and western coasts (Guiry & Guiry, 2015). Comely & Ansell (1988) recorded 28 invertebrate species associated with *Echinus esculentus* from the west coast of Scotland near Oban. These included the parasites *Echinomermella grayi* and *Euonyx chelatus* mentioned above and in addition 4 species of commensal polychaetes, a copepod and 10 amphipod species. The polychaete *Adyte assimilis* and the copepod *Pseudoanthessius liber* were regular commensals amongst the spines. Hyman (1955) states that *Echinus esculentus* is often infested with parasitic copepods e.g. *Asterocheres echinola*. *Echinus esculentus* is susceptible to 'Bald-sea-urchin disease', which causes lesions, loss of spines, tube feet, pedicellariae, destruction of the upper layer of skeletal tissue and death. It is thought to be caused by the bacteria *Vibrio anguillarum* and *Aeromonas salmonicida*. Bald sea-urchin disease was recorded from *Echinus esculentus* on the Brittany Coast. Although associated with mass mortalities of *Strongylocentrotus franciscanus* in California and *Paracentrotus lividus* in the French Mediterranean it is not known if the disease induces mass mortality (Bower 1996). However, no evidence of mass mortalities of *Echinus esculentus* associated with disease have been recorded in the UK.

**Sensitivity assessment.** Based on the available evidence for the characterizing coralline crust, red algae and other associated species the biotope is judged to have 'High' resistance to this pressure as no significant mortalities have been recorded. By default resilience is assessed as 'High' and the biotope is classed as 'Not sensitive' at the pressure benchmark.

#### Removal of target species

**Low**

Q: Low A: NR C: NR

**Medium**

Q: High A: Low C: Medium

**Medium**

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 target species on this biotope. No commercial application or harvesting of encrusting corallines was described in the literature. The calcareous species *Corallina officinalis* is, however, collected for medical purposes; the fronds are dried and converted to hydroxyapatite and used as bone forming material (Ewers *et al.* 1987). It is also sold as a powder for use in the cosmetic industry.

The key characterizing foliose red algal species are not commercially targeted but have been investigated as alternative sources of the phycocolloid substances alginates and agar (Mathieson *et al.*, 1984; Maggs, 1990) and in the future may be subject to harvesting.

The urchin *Echinus esculentus* may be harvested commercially as souvenirs for the tourist trade, or for human consumption (Comely & Ansell, 1988). Nichols (1981, 1984) examined the Cornish sea urchin fishery. It was noted that most commercial divers were inefficient at collecting the sea urchin, as many were obscured by weeds and other debris, or undersides of rocks, so that commercial divers probably leave behind a 'fair proportion' of the population. Intensive collecting did remove all urchins down to 15m from part of Lamora Cove, Cornwall in 1978. But the subsequent diving survey in 1979, showed that the urchins had returned (although no abundance was given), due to migration from deeper waters (Nichols 1981; 1984). At the time of the study (ca 1978-1984) about 0.5 million sea-urchins (*Echinus*) were collected annually. Nichols (1984) concluded that the fishery was sustainable, based on the few years studied. However, he

cautioned against complete clearance due to the adverse effects on habitats. Also natural fluctuations in *Echinus* populations meant that it was not possible to determine an acceptable level of catch. He advised that population densities should not be allowed to fall below 0.2/m<sup>2</sup>, as this population density had been stable at Shallow Tinker Shoal, Plymouth for 24 years (Nichols 1984).

The removal of kelps or brown algae from this biotope would reduce shading and is not considered to negatively affect this biotope (for assessment of removal of the key characterizing species as by-catch, see the removal of non-target species pressure).

**Sensitivity assessment.** The species that are harvested, or potentially harvested, in this biotope are all attached or sedentary and relatively conspicuous. A single event of targeted harvesting could therefore efficiently remove individuals and resistance is assessed as 'Low'. This assessment is supported by evidence from Sharp *et al.*, (1993) on the proportion of biomass of *Chondrus crispus* removed commercially as no specific information was available for characterizing species. Resilience of the red seaweeds is assessed as 'Medium' (based on some damage occurring to perennial holdfasts and bases although see caveats in the resilience section) and biotope sensitivity is assessed as 'Medium'. This assessment refers to a single collection event, long-term harvesting over wide spatial scales will lead to greater impacts, with lower resistance and longer recovery times. Commercial harvesting by divers of *Echinus esculentus* may be relatively inefficient, but at high intensities can remove 100% of the population (within the area impacted) resistance is assessed as 'Low' (significant mortality, 25-75% loss) and resilience is assessed as 'High'. Sensitivity is therefore considered to be 'Low'. The biotope sensitivity is based on the red seaweed assessment.

#### Removal of non-target species

**Low**

Q: Low A: NR C: NR

**Medium**

Q: High A: High C: High

**Medium**

Q: Low A: Low C: Low

Incidental removal of the key characterizing species and associated species would alter the character of the biotope. The biotope is characterized by coralline crusts and red and brown seaweeds. The loss of these due to incidental removal as by-catch would alter the character of the biotope resulting in reclassification 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' and recovery as 'Medium' (based on removal of bases and holdfasts), so that biotope sensitivity is assessed as 'Medium'.

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