Coralline crust-dominated shallow eulittoral rockpools

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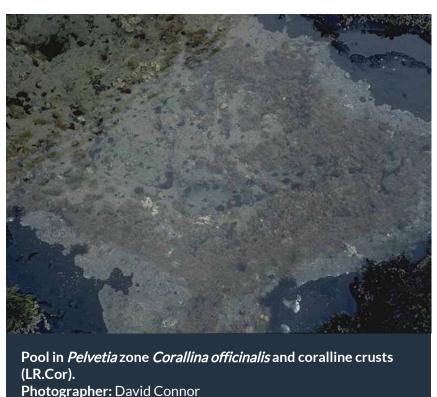
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Pool in *Pelvetia* zone *Corallina officinalis* and coralline crusts (LR.Cor).
Photographer: David Connor
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- Core records
- Non-core, certain determination
- Non-core, uncertain determination
- Predicted habitat extent

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

Researched by   Dr Heidi Tillin & Georgina Budd   **Refereed by**   This information is not refereed.

Summary

☰ UK and Ireland classification

EUNIS 2008	A1.411	Coralline crust-dominated shallow eulittoral rockpools
JNCC 2015	LR.FLR.Rkp.Cor	Coralline crust-dominated shallow eulittoral rockpools
JNCC 2004	LR.FLR.Rkp.Cor	Coralline crust-dominated shallow eulittoral rockpools
1997 Biotope	LR.LR.Rkp.Cor	*Corallina officinalis* and coralline crusts in shallow eulittoral rockpools

🏷 Description

Shallow and smaller rockpools throughout the eulittoral zone in a wide range of wave exposures characterized by a covering of encrusting coralline algae on which *Corallina officinalis* often forms a dense turf. The bottom of these pools can be covered in coarse gravel and cobbles. These 'coralline' pools have a striking appearance as they are dominated by red seaweeds. Foliose red seaweeds found in these pools include *Mastocarpus stellatus*, *Chondrus crispus* and the filamentous

Ceramium nodulosum. The ephemeral green seaweeds *Cladophora rupestris*, *Ulva lactuca* and *Ulva* spp. can also occur in high abundance. The pools may hold large numbers of grazing molluscs, particularly the winkle *Littorina littorea* (which often occur in exceptionally high densities in upper shore pools) and the limpet *Patella vulgata*. Gastropods may graze these pools to such an extent that they are devoid of any foliose red seaweeds, and the flora are reduced to encrusting coralline algae and large numbers of gastropods. Large brown seaweeds are generally absent. Within the pools, pits and crevices are often occupied by the anemone *Actinia equina* and small individuals of the mussel *Mytilus edulis*. The whelk *Nucella lapillus* can be found on the rock surface preying on the barnacles and mussels. A number of variants have been identified. Pools dominated by coralline algae and foliose red seaweeds with a distribution throughout the UK are described as Cor.Cor. In Ireland, the sea urchin *Paracentrotus lividus* can dominate shallow coralline pools to form the variant Cor.Par. In south-west Britain, the abundance of the brown seaweed *Bifurcaria bifurcata* forms the variant Cor.Bif while the abundance of *Cystoseira* spp. forms the variant Cor.Cys. (Information adapted from Connor *et al.*, 2004; JNCC 2015).

⬇ Depth range

Upper shore, Mid shore

🏛 Additional information

In the extreme southwest of Britain, another coralline alga *Jania rubens*, which is similar to *Corallina officinalis*, may occur in large amounts, almost certainly within this biotope.

✔ Listed By

- none -

❧ Further information sources

Search on:

G 𝒈 G JNCC

Habitat review

⟳ Ecology

Ecological and functional relationships

The coralline algae are the dominant species in this biotope. To a great extent the rockpool biotope is an upward extension of ELR.Coff, although the rockpool biotope has its own characteristics.

- *Corallina officinalis* and various lithothamnia are successful in the upper half of the eulittoral zone, especially in shallow, well-lit rockpools (Lewis, 1964). In this zone, some limitation on species develops and not all lower littoral species of the open rock surface can colonize upper shore in rockpools. For example, *Fucus serratus* can do so but *Laurencia pinnatifida*, *Lomentaria articulata* and *Rhodymenia* become much less plentiful, almost to the point of exclusion (Lewis, 1964).
- Other filamentous and foliose red algae found in the pools include *Dumontia contorta*, *Mastocarpus stellatus*, *Ceramium nodulosum* and *Chaetomorpha*, *Ectocarpus*, *Polysiphonia* and *Scytosiphon* species. The green seaweeds *Cladophora rupestris*, *Ulva* spp. and *Ulva lactuca* can also occur in high abundance.
- Seaweeds provide primary productivity either directly to grazing fish and invertebrates or indirectly, to detritivores and decomposers, in the form of detritus and drift algae or as dissolved organic material and other exudates.

The faunal communities of coralline turfs are described in detail by Hagerman (1968), Dommasnes (1968, 1969), Hicks (1985), Grahame & Hanna (1989), Crisp & Mwaiseje (1989), Bamber (1988) and Bamber & Irving (1993). (see ELR.Coff for details).

- *Corallina officinalis* provides substratum for spirorbid worms (e.g. *Spirorbis corallinae*), epiphytes, periphyton, microflora (e.g. bacteria, blue green algae, diatoms and juvenile larger algae), and interstices between the fronds provide refuges from predation for a variety of small invertebrates.
- Amphipods (e.g. *Parajassa pelagica* and *Stenothoe monoculoides*), isopods (e.g. *Idotea pelagica* and *Jaera albifrons*) and other mesoherbivores graze the epiphytic flora and senescent macroalgal tissue, which may benefit the macroalgal host, and may facilitate dispersal of the propagules of some macroalgal species (Brawley, 1992b; Williams & Seed, 1992). Mesoherbivores may also graze the macroalgae but do not normally adversely affect the canopy (Brawley, 1992b). Grazing is likely to be advantageous to encrusting corallines owing to the removal of epiphytes.
- Foliose seaweeds are grazed by large numbers of molluscs, especially the winkle, *Littorina littorea*, the limpet, *Patella vulgata* and top shell, *Steromphala cineraria*. Littorinids show definite preferences for particular algal foods. *Littorina littorea* tends to prefer the green algae such as *Ulva* to perennial red algae (Little & Kitching, 1996). Thin filamentous or membranous seaweeds, such as *Ulva*, *Ceramium* and *Polysiphonia*, are likely to more edible than tougher leathery forms. Some red seaweeds such as *Corallina officinalis* and coralline crusts (*Lithothamnion, Lithophyllum*) protect their thalli with a coating of calcium carbonate and are probably relatively grazing resistant (Littler & Kauker, 1984). Ephemeral algal species may be able to escape herbivory in time and space, owing to the fact that they are less predictable for herbivores, occurring at different times and in different places, usually as a result of disturbance (Raffaelli & Hawkins, 1999). The chiton, *Lepidochitona cinerea* probably grazes the corallines directly.

- Grazers of periphyton (bacteria, blue-green algae and diatoms) or epiphytic algae include harpacticoid copepods, small gastropods (e.g. *Rissoa* spp. and *Littorina neglecta.*
- Within the pools, pits and crevices are likely to be occupied by the beadlet anemone, *Actinia equina* and small mussels, *Mytilus edulis*. The food of anemones consists of a wide variety of crustaceans, molluscs, worms, other invertebrates and even fishes, caught using nematocysts borne on its tentacles.
- The barnacle *Semibalanus balanoides* may be found over the rock surface. It and small mussels, are preyed upon by the whelk, *Nucella lapillus*.

Seasonal and longer term change

As communities in rockpools remain constantly submerged and the danger of desiccation is absent, it might be expected that rockpools form an easier environment in which to live for marine life than drying rock surfaces, and that species from regions lower on the shore would be able to extend much further up the shore. However, much of the lower shore open rock fauna is absent from rockpools. Rockpools constitute a distinct environment for which physiological adaptations by the flora and fauna may be required (Lewis, 1964). Conditions within rockpools are the consequence of prolonged separation from the main body of the sea, and physico-chemical parameters within them fluctuate dramatically (Huggett & Griffiths, 1986). In general, larger and deep rockpools low on the shore tend to correspond to the sublittoral habitat with a more stable temperature and salinity regime. In contrast, small and shallow pools higher on the shore are especially influenced by insolation, air temperature and rainfall, the effects of which become more significant towards the high shore, where pools may be isolated from the sea for a number of days or weeks (Lewis, 1964).

- Weather conditions exert a considerable influence on temperature and salinity. Water temperature in pools follows the temperature of the air more closely than that of the sea. In summer, shallow pools or the surface waters of deeper pools are warmer by day, but may be colder at night, and in winter may be much colder than the sea (Pyefinch, 1943). In deeper pools, the vertical temperature gradation usually present in summer reverses during winter owing to density stratification, so that ice may form (Naylor & Slinn, 1958).
- High air temperatures cause surface evaporation of water from pools, so that salinity steadily increases, especially in pools not flooded by the tide for several days. Alternatively, high rainfall will reduce pool salinity or create a surface layer of brackish/nearly freshwater for a period. The extent of temperature and salinity change is affected by the frequency and time of day at which tidal inundation occurs. If high tide occurs in early morning and evening the diurnal temperature follows that of the air, whilst high water at midday suddenly returns the temperature to that of the sea (Pyefinch, 1943). Heavy rainfall, followed by tidal inundation can cause dramatic fluctuations in salinity, and values ranging from 5-30 psu have been recorded in rockpools over a period of 24 hrs (Ranade, 1957). Rockpools in the supralittoral, littoral fringe and upper eulittoral are liable to gradually changing salinities followed by days of fully marine or fluctuating salinity at times of spring tide (Lewis, 1964).
- Other physico-chemical parameters in rockpools demonstrate temporal change. The biological community directly affects oxygen concentration, carbon dioxide concentration and pH, and are themselves affected by changes in the chemical parameters. Throughout the day, algae photosynthesize and produce oxygen, the concentration of which may rise to three times its saturation value, so that bubbles are released. During photosynthesis algae absorb carbon dioxide and as concentrations fall, the pH rises. Morris & Taylor (1983) recorded pH values >9 in rockpools on the Isle of Cumbrae. At night changes occur

in the opposite direction a respiration utilizes much of the available oxygen and pH decreases.

Corallina officinalis may be overgrown by epiphytes, especially during summer. This overgrowth regularly leads to high mortality of fronds due to light reduction (Wiedemann, pers. comm.). The ephemeral green seaweeds *Ulva intestinalis* and *Ulva lactuca* are likely to be more abundant in summer. In summer, corallines may be bleached and loose their pink pigment but in some species, e.g. *Phymatolithon*, this does not necessarily result in death of the plant and pigment may be re-synthesized (Little & Kitching, 1996).

Habitat structure and complexity

Bedrock forms the substratum of the biotope. Rockpools vary greatly in their physical features. Pools may be shallow and well-lit or deep and shaded with overhanging sides and vertical surfaces. Algae growing within provide additional surfaces for colonization and there is also a tendency for loose substrata (sand, stones, rocks) to accumulate in pools, the instability of which may affect species diversity. Within rockpools, crevices and pits may be found and exploited by species such the mussel *Mytilus edulis* and the beadlet anemone, *Actinia equina*, while the underside of stones and boulders support underboulder communities (see MLR.Fser.Fser.Bo for example).

Productivity

Little information concerning the productivity of coralline turf communities was found. The red algae, algal epiphytes and periphyton provide primary productivity to grazers, while their spores and phytoplankton provide primary productivity to suspension feeders. For instance, spore production by the encrusting 'coralline' algae, *Lithophyllum incrustans* may be up to 18 million m/yr (Edyvean & Ford, 1986).

Secondary productivity of the invertebrate fauna may be high and coralline turf may support high abundances of invertebrates. For example, Choat & Kingett (1982) recorded the following numbers of epiphytic fauna: amphipods 1038 / 0.01m; ostracods 219 / 0.01m.

Recruitment processes

Recruitment processes of some of the characterizing species of the biotope are given below:

- *Corallina officinalis* has isomorphic sexual (gametophyte) and asexual (sporophyte) stages (see *MarLIN* review). Settled tetraspores develop into a perennial crustose base, from which the upright, articulate fronds develop. Sporelings formed within 48 hrs, a crustose base within 72 hrs, fronds being initiated after 3 weeks and the first intergeniculum (segment) formed within 13 weeks of settlement (Jones & Moorjani, 1973). Settlement and development of fronds is optimal on rough surfaces but settlement can occur on smooth surfaces (Harlin & Lindbergh, 1977; Wiedeman pers. comm.). *Corallina officinalis* settled on artificial substrata within 1 week of their placement in the intertidal in New England summer suggesting that recruitment is high (Harlin & Lindbergh, 1977).
- Besides having a meristem, *Lithophyllum incrustans* has its conceptacles (reproductive organs) buried in its calcified thallus, and connected to the exterior by canals (Edyvean & Ford, 1986). Reproductive types (gametangial and tetrasporangial plants) occur from October to April but decline into summer although some conceptacles are present throughout the year (Irvine & Chamberlain 1994). It has been calculated that 1 mm x 1mm of reproductive thallus produces 17.5 million bispores per year with average settlement

of only 55 sporelings/year (Edyvean & Ford 1984).

- All the spores of red algae are non flagellate and dispersal is wholly a passive process (Fletcher & Callow, 1992). Spores vary in their sinking rate as determined by size and density. In general, due to the difficulties of re-entering the benthic boundary layer, it is likely that successful colonization is achieved under conditions of limited dispersal and/or minimum water current activity. Norton (1992) reported that although spores may travel long distances the reach of the furthest propagule does not equal its useful dispersal range, and most successful recruitment probably occurs within 10m of the parent plants. It is expected, therefore, that recruitment of foliose macroalgae in the biotope would occur from local populations and that establishment and recovery of isolated populations would be patchy and sporadic.
- *Littorina littorea* is an iteroparous breeder with high fecundity (up to 100,000 for a large female (27 mm shell height)) that lives for several (at least 4) years. *Littorina littorea* can breed throughout the year but the length and timing of the breeding period are extremely dependent on climatic conditions. *Littorina littorea* sheds egg capsules directly into the sea and release is synchronized with spring tides on several separate occasions. Larval settling time or pelagic phase can be up to six weeks (Fish, 1972).
- Recruitment of *Patella vulgata* fluctuates from year to year and from place to place (Bowman, 1981). Fertilization is external and the larvae are pelagic for up to two weeks before settling on rock at a shell length of about 0.2 mm. Winter breeding occurs only in southern England, in the north of Scotland it breeds in August and in north-east England in September.
- Gammarid amphipods brood their embryos and offspring but are highly mobile as adults and probably capable of colonizing new habitats from the surrounding area (e.g. see *Hyale prevostii* review). Similarly isopods such as *Idotea* species and *Jaera* species brood their young. *Idotea* species are mobile and active swimmers and probably capable of recruiting to new habitats from the surrounding area by adult migration. *Jaera albifrons*, however, is small and may take longer to move between habitats and Carvalho (1989) suggested that under normal circumstances movement was probably limited to an area of less than 2 m. Hicks (1985) noted that epiphytic harpacticoid copepods lack planktonic dispersive larval stages but are active swimmers, which is therefore the primary mechanism for dispersal and colonization of available habitats. Some species of harpacticoids are capable to moving between low and mid-water levels on the shore with the tide, while in others, colonization rates decrease with increasing distance from the resident population. Overall immigration and *in situ* reproduction were thought to maintain equilibrium populations exposed to local extinction, although there may be local spatial variation in abundance (see Hicks, 1985).

Time for community to reach maturity

The epiphytic species diversity of the coralline turf in the rockpool is dependant on the *Corallina officinalis* cover and its growth form (Dommasnes, 1968, 1969; Seapy & Littler, 1982; Crisp & Mwaiseje, 1989). *Corallina officinalis* was shown to settle on artificial substances within 1 week of their placement in the intertidal in New England summer suggesting that recruitment is high (Harlin & Lindbergh, 1977). New fronds of *Corallina officinalis* appeared on sterilized plots within six months and 10% cover was reached with 12 months (Littler & Kauker, 1984). In experimental plots, up to 15% cover of *Corallina officinalis* fronds returned within 3 months after removal of fronds and all other epiflora/fauna (Littler & Kauker, 1984). Bamber & Irving (1993) reported that new plants grew back in scraped transects within 12 months, although the resistant crustose bases were probably not removed. New crustose bases may recruit and develop quickly but the

formation of new fronds from these bases and recovery of original cover may take longer. Once a coralline turf has developed it will probably be colonized by epiphytic invertebrates such as harpacticoids, amphipods and isopods relatively quickly from the surrounding area. Therefore, the biotope would be recognizable once the coralline turf has regrown, which is likely to be quite rapid if the resistant crustose bases remain. Recruitment of red algae probably equally rapid, and once the algal turf has developed most of the epiphytic invertebrates would colonize quickly, although some species e.g. small brooding gastropods would take longer.

Additional information

No text entered.

🖼 Preferences & Distribution

Habitat preferences

Depth Range	Upper shore, Mid shore
Water clarity preferences	No information found
Limiting Nutrients	Nitrogen (nitrates), Phosphorus (phosphates)
Salinity preferences	Full (30-40 psu)
Physiographic preferences	
Biological zone preferences	Eulittoral, Lower littoral fringe
Substratum/habitat preferences	Bedrock, Large to very large boulders, Small boulders
Tidal strength preferences	No information
Wave exposure preferences	Exposed, Moderately exposed, Sheltered, Very exposed
Other preferences	Rockpools

Additional Information

No text entered.

✤ Species composition

Species found especially in this biotope

- *Corallina officinalis*
- *Lithophyllum incrustans*

Rare or scarce species associated with this biotope

-

Additional information

The MNCR recorded ca 577 species in 176 records of this biotope, although not all species occurred in all records of the biotope (Connor *et al.*, 1997b; JNCC, 1999).

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

Shallow and smaller rockpools throughout the eulittoral zone in a wide range of wave exposures may be characterized by a covering of encrusting coralline algae on which *Corallina officinalis* often forms a dense turf. The coralline crusts and turfs of *Corallina officinalis* are considered the key characterizing and structuring species within the biotope and the sensitivity assessments focus on these species (although information on coralline crusts is limited). The bottom of the pools can be covered in coarse gravel and cobbles. Foliose red seaweeds found in these pools include *Mastocarpus stellatus, Chondrus crispus* and the filamentous *Ceramium nodulosum*. The ephemeral green seaweeds *Cladophora rupestris, Ulva lactuca* and *Ulva* spp. can also occur in high abundance. The sensitivity assessments describe the sensitivity of the red and green species in general terms The pools may hold large numbers of grazing molluscs, particularly the winkle *Littorina littorea* (which often occur in exceptionally high densities in upper shore pools) and the limpet *Patella vulgata*. Gastropods may graze the red and green foliose algae in these pools to such an extent that they are devoid of any foliose red seaweeds, and the flora are reduced to encrusting coralline algae and large numbers of gastropods. As the grazers are key structuring species they are also considered within the sensitivity assessments. Within the pools, pits and crevices are often occupied by the anemone *Actinia equina* and small individuals of the mussel *Mytilus edulis*. The whelk *Nucella lapillus* can be found on the rock surface preying on the barnacles and mussels. These common rocky shore species while contributing to species diversity and ecological function within the biotope are not considered to be key to the biotope and are therefore only generally referred to within the assessments. The sensitivity assessments presented here are considered relevant to LR.FLR.Rkp.Cor (A1.411) and the *Corallina officinalis* dominated biotope LR.FLR.Rkp.Cor.Cor (A1.4111). The variant biotopes A1.4112 (LR.FLR.Rkp.Cor.Par); A1.4113 (LR.FLR.Rkp.Cor.Bif); A1.4114 (LR.FLR.Rkp.Cor.Cys) and A1.421 (LR.FLR.Rkp.FK.) are assessed separately due to differences in the key characterizing species (*Paracentrotus lividus*; *Bifurcaria bifurcata*; *Cystoseira* spp. and *Sargassum muticum* respectively).

Resilience and recovery rates of habitat

Coralline algae are red algae (Rhodophyta) characterized by a 'stony' thallus because of calcareous deposits contained within the cell walls. Although ubiquitous in marine coastal systems little is understood about the taxonomy, biology and ecology of these taxa (Littler & Littler, 2013). 'Coralline crust' is a generic term that, in UK biotopes, refers to non-geniculate (crustose) species from the family Corallinacea that could include *Lithophyllum incrustans*, which forms thick crusts in tidepools, especially in the south-west (Adey & Adey, 1973), *Lithothamnion* spp. and *Phymatolithon* spp. Throughout the sensitivity assessments, the term coralline crust is used to refer to the Corallinacea within the biotope. Due to the lack of evidence for species the assessments are generic, although species-specific information is presented where available. *Corallina officinalis* is a geniculate (articulated) species that occurs as a dense turf in this biotope. The fronds grow from a crustose base, similar to a coralline crust.

Where this biotope is impacted by pressures, recolonization of the key structuring and characterizing coralline crust and the turf of *Corallina officinalis* will require either regrowth from surviving holdfast or basal crusts or recolonization by propagules. The crustose holdfast or base of *Corallina officinalis* is perennial and grows apically (continuous growth at tips), similar to encrusting corallines such as *Lithothamnia* sp. The basal crust may grow continuously until stimulated to produce fronds (Littler & Kauker 1984; Colhart & Johanssen 1973). Littler & Kauker (1984)

suggest that the crustose bases were adapted to resist grazing and desiccation whereas the fronds were adapted for higher primary productivity and reproduction. The basal crusts are tougher than the upright fronds (requiring a pressure of 94 g/mm^2 to penetrate compared to 43 g/mm^2). Regeneration of the basal crusts provides a more rapid route to recovery than recolonization. Experiments in the intertidal in southern California found that areas scraped back to crusts recovered four times more rapidly than sterilised plots where the crusts were removed (Littler & Kauker, 1984).

In culture, *Corallina officinalis* fronds exhibited an average growth rate of 2.2 mm/month at 12 and 18°C. The growth rate was only 0.2 mm/month at 6°C and no growth was observed at 25°C (Colhart & Johanssen 1973). Similarly, Blake & Maggs (2003) observed much higher growth rates of 2 mm/month over six months starting from September in *Corralina officinalis* grown in Strangford Lough (Northern Ireland) at 5 and 10m depth, these rates are similar to those observed by Andrake & Johansen, (1980) in winter in New Hampshire. The evidence for growth rate suggests that to achieve a height of 10 cm the turf would be at least 4 years old (probably older as higher temperatures appear to slow growth. A low-level turf of, for example 5 cm, could theoretically be achieved within 2 years.

Where the bases are removed, recovery will depend on recolonization. Areas that are cleared during the reproductive period have the potential to be rapidly colonized. *Corallina officinalis* was shown to settle on artificial substances within 1 week of their placement in the intertidal in New England summer (Harlin & Lindbergh, 1977). However, settlement plates laid out in the autumn were not recolonized until the next spring. In the lower rocky intertidal in southern California dominated by *Corallina officinalis* with foliose overstorey algae present, in this habitat, Littler & Kauker (1984) experimentally cleared plots and followed the recovery for 12 months. Some areas were scraped allowing the basal crusts to remain whereas others were completely sterilised (removal of all material and surfaces then scorched with a blow torch to remove bases). In scraped plots, up to 15% cover of *Corallina officinalis* fronds returned within 3 months after removal of fronds and all other epiflora/fauna while in sterilized plots (all basal crusts removed) appearance of articulated fronds occurred 6 months following clearance (Littler & Kauker, 1984). At the end of the 12 month observation period *Corallina officinalis* cover had increased to approximately 18% in plots where basal crusts remained and to approximately 10% in sterilised plots. Similarly, Bamber & Irving (1993) reported that new plants grew back in scraped transects within 12 months, although the resistant crustose bases were probably not removed.

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

potential importance of grazers to the re-establishment of this biotope.

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 & Ford (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 fewer 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. 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 (1984a) 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, 1984a). 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* oil 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 two months. As encrusting corallines are sensitive to desiccation (Dethier, 1994) it should be noted that these subtidal habitats are probably more favourable for recruitment, growth and survival than intertidal rock pools.

Resilience assessment. The resilience of the biotope is assessed as **'High'** where resistance is 'High' (no significant impact) or 'Medium' (where <25 % of *Corallina officinalis* fronds or encrusting corallines are removed and coralline crusts remain), based on regrowth from the basal crusts and vegetative growth from surrounding turfs or crusts. Where resistance is assessed as 'Low' or 'None' then resilience is assessed as **'Medium'** (2-10 years) for the *Corallina officinalis* turf and encrusting corallines. Recovery of the age structure of the coralline crusts may require longer, as these can be long-lived, but where recolonization and cover by younger crusts have occurred the age structure of the crusts is not considered to substantially alter the character of the biotope. Once a coralline turf has developed it will probably be colonized by epiphytic invertebrates such as harpacticoids, amphipods and isopods relatively quickly from the surrounding area. Therefore, the biotope would be recognizable once the coralline turf has regrown, which is likely to be quite rapid if the resistant crustose bases remain. The clearance experiments by Littler & Kauker (1984) suggest that recovery of a dense turf cover whether basal crusts remained or were totally removed would require more than two years. Presumably, as crusts can grow in all directions percentage cover is not a linear function and that gap closure would speed up with greater cover. Recruitment of associated species of red algae is probably equally rapid, and once the algal turf has

developed most of the epiphytic invertebrates would colonize quickly, although some species e.g. small brooding gastropods could take longer. The ephemeral green algae associated with the biotope are opportunist colonizers of gaps and would be expected to recover within a year. Where perturbations have a large spatial footprint with the widespread removal of crusts over a large area then the development of an alternate state emerging with dominance by canopy-forming algae is a possibility. In such an instance, recovery could take much longer and depend on active management or further perturbations. No evidence was found however to determine when such shifts might occur.

Note: the resilience and the ability to recover from human induced pressures is a combination of the environmental conditions of the site, the frequency (repeated disturbances versus a one-off event) and the intensity of the disturbance. Recovery of impacted populations will always be mediated by stochastic events and processes acting over different scales including, but not limited to, local habitat conditions, further impacts and processes such as larval-supply and recruitment between populations. Full recovery is defined as the return to the state of the habitat that existed prior to impact. This does not necessarily mean that every component species has returned to its prior condition, abundance or extent but that the relevant functional components are present and the habitat is structurally and functionally recognizable as the initial habitat of interest. It should be noted that the recovery rates are only indicative of the recovery potential.

🚢 Hydrological Pressures

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

Species found in the intertidal are exposed to extremes of high and low air temperatures during periods of emersion. They must also be able to cope with sharp temperature fluctuations over a short period of time during the tidal cycle. In winter, air temperatures are colder than the sea, conversely in summer air temperatures are much warmer than the sea. Species that occur in this intertidal biotope are therefore generally adapted to tolerate a range of temperatures, although the timing of site-specific factors such as low tides will influence local acclimation. For intertidal species, increased temperatures may also result in desiccation when exposed (see changes in emergence pressure).

The key characterizing species, *Corallina officinalis* 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. Coralline crusts, including *Lithophyllum incrustans,* are found further south than the UK and are considered to tolerate increased temperatures, although they may be more sensitive to drying rather than higher temperatures. 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 tide pools with a smaller volume of water, which 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 & Forde, 1984b). *Lithophyllum incrustans* is close to the northern edge of its range and is likely to tolerate increased

temperatures.

Littler & Kauker (1984) suggested that the crustose bases of *Corallina officinalis* are more resistant of desiccation or heating than fronds. Severe damage was noted in *Corallina officinalis* fronds as a result of desiccation during unusually hot and sunny weather in summer 1983. An abrupt increase in temperature of 10°C caused by the hot, dry 'Santa Anna' winds (between January -and February) in Santa Cruz, California resulted in die back of several species of algae exposed at low tide (Seapy & Littler, 1982). Lüning (1990) reported that *Corallina officinalis* from Helgoland survived one week exposure to temperatures between 0°C and 28°C.

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

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 3°C, the *Corallina was* completely bleached after three days with a sample kept at 30°C beginning to bleach. After seven days (the end of the experiment) the sample kept at 30°C was partially bleached. Samples kept at 5, 15, 20 and 25°C showed little change in chemicals produced in reaction to thermal stress and no bleaching suggesting the temperatures in that range had not induced stress reactions.

Most of the other species within the biotope are distributed to the north and south of Britain and Ireland and unlikely to be adversely affected by a chronic long-term temperature change. *Ulva* spp. are characteristic of upper shore rockpools, where water and air temperatures are greatly elevated on hot days. Empirical evidence for thermal tolerance to anthropogenic increases in temperature is provided by the effects of heated effluents on rocky shore communities in Maine, USA. *Ascophyllum* and *Fucus* were eliminated from a rocky shore heated to 27-30°C by a power station whilst *Ulva intestinalis* (as *Enteromorpha intestinalis*) increased significantly near the outfall (Vadas *et al.*, 1976). Barnacles *Semibalanus balanoides*, limpets *Patella vulgata* and littorinids also occur within this biotope. Laboratory studies suggest that adults of these species can tolerate temperature increases. The median upper lethal temperature limit in laboratory tests on *Littorina littorea*, *Littorina saxatilis* and *Semibalanus balanoides* was approximately 35°C (Davenport & Davenport, 2005). *Patella vulgata* can also tolerate high temperatures. The body temperature of *Patella vulgata* can exceed 36°C in the field, (Davies, 1970); adults become non-responsive at 37-38°C and die at temperatures of 42°C (Evans, 1948). The smaller species associated with the *Corallina officinalis* may be protected within fronds and accumulated sediments from changes in temperature although no direct evidence was found to assess the sensitivity of these to increased temperatures.

Sensitivity assessment. Based on the global distribution of *Corallina officinalis* and the experiments by Latham (2008) which approximate to the pressure benchmark more than the observations of extreme events (Seapy & Littler, 1982, Hawkins & Hartnoll, 1985) it is suggested that *Corallina officinalis* would not be sensitive to either an acute or chronic increase in temperature at the pressure benchmark. Littler & Littler (1983) suggest that the basal crustose stage is adaptive as

resisters of sand scour and wave shearing as well as physiological stressors such as desiccation and heating. Where these survive any increases in temperature above the pressure benchmark they would provide a mechanism for biotope recovery. The distribution of *Lithophyllum incrustans* and other crusting corallines in southern Europe and the Mediterranean suggest that these are tolerant of higher temperatures. The sensitivity of the biotope is based on the key characterizing *Corallina* turf but it should be noted that many of the associated species are considered to have 'High' resistance to changes in temperature at the pressure benchmark. Therefore, resistance is assessed as **'High'**, resilience as **'High'** (by default) and sensitivity assessed as **'Not sensitive'** at the benchmark level. It should be noted that the timing of acute and chronic increases would alter the degree of impact and hence sensitivity. An acute change occurring on the hottest day of the year and exceeding thermal tolerances would lead to mortality. The sensitivity of *Patella vulgata* to longer-term, broad-scale perturbations would potentially be greater due to effects on reproduction but these changes may lead to species replacements and are not considered to significantly affect the character of the biotope.

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

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

Under extremely low temperatures, components of the community demonstrate tolerance. Lüning (1990) reported that *Corallina officinalis* from Helgoland survived 0°C when exposed for one week. New Zealand specimens were found to tolerate -4°C (Frazer *et al.*, 1988). Lüning (1990) suggested that most littoral algal species were tolerant of cold and freezing. For example, the photosynthetic rate of *Chondrus crispus* recovered after 3 hrs at -20°C but not after 6 hrs (Dudgeon *et al.*, 1990). The photosynthetic rate of *Mastocarpus stellatus* higher on the shore fully recovered from 24 hrs at -20°C. 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 (Edyean & Ford, 1984b).

The associated species are also likely to be tolerant of a decrease in temperature at the pressure benchmark. *Mytilus edulis* and *Ulva* spp. are eurytopic, found in a wide temperature range and in areas which frequently experience freezing conditions and are vulnerable to ice scour (Seed & Suchanek 1992). The tolerance of *Semibalanus balanoides* collected in the winter (and thus acclimated to lower temperatures) to low temperatures was tested in the laboratory. The median lower lethal temperature tolerance was -14.6°C (Davenport & Davenport, 2005). A decrease in temperature at the pressure benchmark is therefore unlikely to negatively affect this species. The same series of experiments indicated that median lower lethal temperature tolerances for *Littorina saxatilis* and *Littorina littorea* were -16.4 and -13°C respectively. Adults of *Patella vulgata* are also largely unaffected by short periods of extreme cold. Ekaratne & Crisp (1984) found adult limpets continuing to grow over winter when temperatures fell to -6°C and stopped only by still more severe weather. However, loss of adhesion after exposure to -13°C has been observed with limpets falling off rocks and therefore becoming easy prey to crabs or birds (Fretter & Graham,
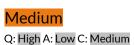
1994). However, in the very cold winter of 1962-3 when temperatures repeatedly fell below 0°C over a period of two months large numbers of *Patella vulgata* were found dead (Crisp, 1964). Periods of frost may also kill juvenile *Patella vulgata*, resulting in recruitment failures in some years (Bowman & Lewis, 1977). In colder conditions, an active migration by mobile species may occur down the shore to a zone where exposure time to the air (and hence time in freezing temperatures) is less.

Sensitivity assessment. Based on the characterizing and associated species, this biotope is considered to have **'High'** resistance and **'High'** resilience (by default) to this pressure and is, therefore, considered to be **'Not sensitive'.** The timing of changes and seasonal weather could result in greater impacts on species. An acute decrease in temperature coinciding with unusually low winter temperatures may exceed thermal tolerances and lead to mortalities of the associated species although this would not alter the character of the biotope.

Salinity increase (local)	Low	Medium	Medium
	Q: High A: Medium C: Medium	Q: High A: Low C: Medium	Q: High A: Low C: Medium

This biotope is found in full (30-35 ppt) salinity (Connor *et al.*, 2004). High air temperatures cause surface evaporation of water from pools so that salinity steadily increases. The extent of temperature and salinity change is affected by the frequency and time of day at which tidal inundation occurs. Heavy rainfall, followed by tidal inundation can cause dramatic fluctuations in salinity, and values ranging from 5-30 psu have been recorded in rockpools over a period of 24 hrs (Ranade, 1957) while Newell (1979) recorded salinities as high as 42 psu in intertidal rock pools. As a consequence of such a regime, the entire rockpool community will be adapted, to a certain degree, to fluctuating salinities. However, it should be noted that local populations may be acclimated to the prevailing salinity regime and may, therefore, exhibit different tolerances to other populations subject to different salinity conditions and therefore caution should be used when inferring tolerances.

The characterizing species *Corallina officinalis* and crustose corallines are found in rockpools, such as this biotope, where salinities may fluctuate markedly during exposure to the air. Kinne (1971) cites maximal growth rates for *Corallina officinalis* between 33 and 38 psu in Texan lagoons. Edyvean & Ford (1984b) suggest that populations of *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, which 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).

The associated species are typically found in a range of salinities. *Ulva* species can survive hypersaline conditions in supralittoral rockpools subjected to evaporation and is considered to be a very euryhaline species, tolerant of extreme salinities ranging from 0 psu to 136 psu (Reed & Russell, 1979). Young *Littorina littorea* inhabit rockpools where salinity may increase above 35 psu. Thus, key species may be able to tolerate some increase in salinity. *Mytilus edulis* is found in a wide range of salinities from variable salinity areas (18-35 ppt) such as estuaries and intertidal areas to areas of more constant salinity (30-35 ppt) in the sublittoral (Connor *et al.*, 2004). Furthermore, mussels in rockpools are likely to experience hypersaline conditions on hot days, suggesting that *Mytilus edulis* can tolerate high salinities.

Sensitivity assessment. No direct evidence was found to assess sensitivity to this pressure. Although some increases in salinity may be tolerated by the associated species present the natural variation, (rather than the pressure benchmark) is generally short-term and mitigated during tidal inundation. This biotope is considered to be sensitive to a persistent increase in salinity to > 40 ppt, based on the distribution of *Corallina officinalis* and the encrusting corallines on the mid to lower shore. Therefore, resistance is assessed as '**Low'** and resilience as **'Medium'** (following restoration of the prior salinity regime) so that sensitivity is assessed as **'Medium'.**

Salinity decrease (local)	Low	Medium	Medium
	Q: High A: Medium C: Low	Q: High A: Low C: Medium	Q: High A: Low C: Low

This biotope is recorded in full salinity habitats (Connor *et al*., 2004). However, high rainfall will reduce salinity in rockpools when exposed to air and may create a surface layer of brackish/nearly freshwater for a period. Heavy rainfall, followed by tidal inundation can cause dramatic fluctuations in salinity, and values ranging from 5-30 psu have been recorded in rockpools over a period of 24 hrs (Ranade, 1957). As a consequence of such a regime, the entire rockpool community will be adapted, to a certain degree, to fluctuating salinities.

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

Based on their occurrence in estuaries, it is clear that some of the species associated with this biotope have a high tolerance for this pressure. However, it should be noted that local populations may be acclimated to the prevailing salinity regime and may, therefore, exhibit different tolerances to other populations subject to different salinity conditions so that caution should be used when inferring tolerances from populations in different regions. *Ulva* species are considered to be a very euryhaline species, tolerant of extreme salinities ranging from 0 psu to 136 psu (Reed & Russell, 1979). Although some variation in salinity tolerance between populations of *Ulva intestinalis* has been found indicating that plants have some adaptation to the local salinity regime (Reed & Russell, 1979). *Littorina littorea* is found in waters of full, variable and reduced salinities (Connor *et al*., 2004) and so populations are considered tolerant of decreases in salinity at the pressure benchmark. *Mytilus edulis* is found in a wide range of salinities from variable salinity areas (18-35ppt) such as estuaries and intertidal areas to areas of more constant salinity (Connor *et al*., 2004).   *Mytilus edulis* was recorded to grow in a dwarf form in the Baltic sea where the average salinity was 6.5 psu (Riisgård *et al*., 1993).

In the long-term (weeks) *Mytilus edulis* can acclimate to lower salinities (Almada-Villela, 1984; Seed & Suchanek 1992; Holt *et al*.,1998). Almada-Villela (1984) reported that the growth rate of individuals exposed to only 13 psu reduced to almost zero but had recovered to over 80% of

control animals within one month. In extreme low salinities, e.g. resulting from storm runoff, large numbers of mussels may be killed (Keith Hiscock pers comm). However, Bailey *et al.*, (1996) observed very few mortalities when exposing *Mytilus edulis* to a range of salinities as low as 0ppt for two weeks at a range of temperatures. It was also noted that there was a fast recovery rate.

Prolonged reduction in salinity, e.g. from full (30-40 ppt) to reduced (18-30 ppt), is likely to reduce the species richness of the biotope due to loss of some intolerant invertebrates from the assemblage associated with the *Corallina officinalis* turf.

Sensitivity assessment. Although some daily changes in salinity may be experienced these will be mitigated during tidal inundation. This biotope is considered, based on *Corallina officinalis* distribution and the evidence from Kinne, (1971), to be sensitive to a decrease in salinity at the pressure benchmark. Therefore, resistance is assessed as **'Low'** and recovery as '**Medium'** (following restoration of the prior salinity regime) so that sensitivity is assessed as **'Medium'**.

Water flow (tidal current) changes (local)	High	High	Not sensitive
	Q: High A: High C: High	Q: High A: High C: High	Q: High A: High C: High

No evidence to assess this pressure was found. The rockpool habitat will provide some protection from water flows although surface topography may create some turbulence disrupting currents. The coralline crusts characterizing this biotope are securely attached and as these are flat are subject to little or no drag. As biotopes dominated by turfs of *Corallina officinalis* and containing similar associated species are found in a range of flow rates from 'moderately strong' (0.5-1.5 m/s) to very 'weak' negligible) (Dommasnes, 1969; Connor *et al.*, 2004) this key characterizing and structuring species and associated red and green algae and limpets and littorinids are . Moderate water movement is beneficial to seaweeds as it carries a supply of nutrients and gases to the plants and removes waste products. However, if the flow becomes too strong, plants may become displaced. In addition, an increase to stronger flows may inhibit settlement of spores and remove adults or germlings. However, *Corallina officinalis* have a compact, turf-forming growth which reduces water flow through turbulence and friction and are probably resistant to displacement by an increase in water flow.

Sensitivity assessment. Hence, this biotope is considered to have **'High'** resistance and **'High'** resilience to this pressure at the benchmark and is assessed as '**Not sensitive'**. Changes in water flow at the pressure benchmark may result in increased or decreased sediment deposition but these changes are not considered to alter the character of the biotope although they may alter species richness of the small invertebrates associated with the turf or any sediment deposits.

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

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

The occurrence of encrusting coralline algae is critically determined by exposure to air and sunlight. Colonies survive in damp conditions under algal canopies or in pools but not on the open rock where desiccation is important. Increased emergence leading to drying out of shallow pools would reduce habitat suitability for this group. Spore release by the crusting coralline *Lithophyllum incrustans* is triggered by small changes in salinity and temperature and therefore changes in emergence may alter patterns in reproduction and recruitment (see relevant pressures for further information). However, this species does occur both high and low in the intertidal (Edyvean & Ford, 1986) and presumably, such impacts are limited

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

The associated *Ulva* spp. are able to tolerate desiccation stress they are often very abundant on the high shore where desiccation stress is the primary factor controlling seaweed distribution, and may even be found above the tidal limits of the shore. *Ulva intestinalis* (studied as *Enteromorpha intestinalis*) can survive several weeks of living in completely dried out rock pools while becoming completely bleached on the uppermost layers, but remaining moist underneath the bleached fronds. However, desiccation stress of germlings may be lower than adults. Hruby & Norton (1979) found that 7-14 day old germlings of *Ulva* (studied as *Enteromorpha*) were more tolerant of desiccation than earlier stages, so an increase in desiccation stress may impact more adversely on newly settled germlings than more mature plants. Owing to increased emergence, the species that graze on *Ulva intestinalis* are likely to be less active, owing to the risk of desiccation, and the seaweed may benefit from reduced grazing pressure.

Mobile epifauna are likely to seek shelter elsewhere and species such as *Patella vulgata* and *Littorina littorea* are found throughout the intertidal zone are likely to tolerate increased emergence particularly where the pool ameliorates desiccation stress and temperature increases. An increase in emergence may result in migration down the shore, while decreased emergence may increase habitat suitability of upper littoral fringe biotopes for these species. Grazing by littorinids and other species can have a significant structuring impact on this biotope by removing red and green algae (Robles 1982, Albrecht, 1998). An increase in grazers and grazing within this biotope may removal large amounts of algal biomass. However, this would not alter the classification of this biotope but may alter classification between the variant sub-biotopes. The blue mussel *Mytilus edulis* occurs within this biotope and is found at a wide range of shore heights from in the strandline down to the shallow sublittoral (Connor *et al.*, 2004). Their upper limits are controlled by temperature and desiccation (Suchanek, 1978; Seed & Suchanek 1992; Holt *et al.*, 1998) while the lower limits are set by predation, competition (Suchanek, 1978) and sand burial (Daly & Mathieson, 1977). A significant, long-term, increase in emergence placing this biotope in the upper intertidal is therefore likely to lead to the replacement of this biotope with one more typical of the changed conditions, barnacles and mussels or green algae for example.

Sensitivity assessment. A decrease in emergence would mean that shallow rockpools would be at less risk of desiccation. In addition, depending on the nature of the surrounding bedrock, the rockpool may become slightly deeper. As a result, it is possible that species diversity could increase but, on the whole biotopes at the upper and mid-shore are likely to be tolerant of a decrease in emergence at the benchmark level. Pre-emption of space by *Corallina officinalis* and other red algae may reduce the establishment of lower shore species including kelps. Therefore, resistance is assessed as **'Medium'** to **decreased emergence** and resilience as **'High'** so that sensitivity is

assessed as **'Low'**. Resistance to **increased emergence** is also assessed as **'Medium'** as the coralline crusts *Corallina officinalis* and associated red algae are intolerant of desiccation but are generally protected by the pool environment. Resilience is assessed as **'High'** and sensitivity is, therefore, assessed as **'Low'**. An increase in emergence repositioning the biotope at an upper shore level would be likely to significantly affect the species composition due to increased temperatures and greater variation in salinity and sensitivity would be greater.

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

This biotope is recorded from locations that range from very exposed, to sheltered (Connor *et al.*, 2004), while Dommasnes, (1969) recorded *Corallina officinalis* turfs from very wave sheltered areas in Norway. Colonies of *Lithophyllum incrustans* appear to thrive in conditions exposed to strong water movement. Irvine & Chamberlain (1994) observe that the species is best developed on wave exposed shores. 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.

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'** at the benchmark level.

⚗ Chemical Pressures

	Resistance	Resilience	Sensitivity
Transition elements & organo-metal contamination	Not Assessed (NA)	Not assessed (NA)	Not assessed (NA)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

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

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

Most of the information available suggests that adult gastropod molluscs are rather tolerant of heavy-metal toxicity (Bryan, 1984). Winkles may absorb metals from the surrounding water by absorption across the gills or from their diet, and evidence from experimental studies on *Littorina*

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

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

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 'Lithothamnia' following the *Sea Empress* oil spill. Observations following the *Don Marika* oil spill (K. Hiscock, pers. comm.) were of rockpools with completely bleached coralline algae. However, Chamberlain (1996) observed that although *Lithophyllum incrustans* was affected in a short period of time by oil during the *Sea Empress* spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area.

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

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

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 plans 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 a 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 an intertidal population of *Corallina officinalis* occurred in significant amounts only 600 m east of the effluent. Chamberlain (1996) observed that although *Lithophyllum incrustans* was quickly affected by oil during the *Sea Empress* spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area.

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

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

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

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

This pressure is **Not assessed.**

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

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

Vidaver, 1972). This biotope would only be exposed to low oxygen in the water column intermittently during periods of tidal immersion. In addition, in areas of wave exposure and moderately strong current flow, low oxygen levels in the water are unlikely to persist for very long as oxygen levels will be recharged by the incorporation of oxygen in the air into the water column or flushing with oxygenated waters.

No evidence was found to assess this pressure for the red algae turfs. However, the associated species are unlikely to be impacted by this pressure, at the benchmark. Experiments have shown that thallus discs of *Ulva lactuca* plants can survive prolonged exposure to anoxia and hypoxia (Vermaat & Sand-Jensen, 1987; Corradi *et al.*, 2006). Following the resumption of normal oxygen conditions, gametes were produced. The associated invertebrate species also show high tolerances for reduced oxygen at levels that exceed the pressure benchmark. *Littorina littorea* can easily survive 3-6 days of anoxia (Storey *et al.*, 2013). Limpets can also survive for a short time in anoxic seawater. Grenon & Walker, (1981) found that in oxygen-free water limpets could survive up to 36 hours, although Marshall & McQuaid (1989) found a lower tolerance for *Patella granularis*, which survived up to 11 hours in anoxic water. *Patella vulgata* and *Littorina littorea* are able to respire in the air, mitigating the effects of this pressure during the tidal cycle.

Sensitivity assessment. No direct evidence for the effects of hypoxia on red algal turfs was found. As the biotope will only be exposed to this pressure when submerged and respiration will occur in air, biotope resistance was assessed as **'High'** and resilience as **'High'** (no effect to recover from), resulting in a sensitivity of **'Not sensitive'.**

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

This pressure relates to increased levels of nitrogen, phosphorus and silicon in the marine environment compared to background concentrations. The pressure benchmark is set at compliance with the Water Framework Directive (WFD) criteria for good status, based on nitrogen concentration (UKTAG, 2014). No evidence was found to assess the sensitivity of the key characterizing species, *Sargassum muticum*. Marine algae are often nutrient limited, by nitrogen in particular, so an increase in nutrient levels usually results in increased growth and fecundity. In the Bay of Fundy, for example, where there is a tidal flux of nutrients from the marshes there is a luxurious growth of *Palmaria palmata* (Morgan *et al*., 1980). However, very high levels of nutrients can be toxic to macroalgae. Plants placed in tanks with continuous immersion in high nutrients over several weeks stopped growing (Morgan *et al*., 1980). In general, the great majority of reports refer to an increase in the number of green algae associated with eutrophicated waters, usually at the expense of red and brown algae.

Over geological timescales periods of increased nutrient availability have experienced increases in the distribution of crustose coralline species at the expense of corals (Littler & Littler, 2013), suggesting that this group have some tolerance for enhanced nutrient levels. Overall, Littler & Littler (2013) suggest that corallines as a group can tolerate both low and elevated levels of nutrients. The key characterizing *Corallina officinalis* and the associated green algae species have been identified worldwide as species that occur in areas subject to increased nutrient input within the vicinity of sewage outfalls and at intermediately polluted sites (Littler & Murray, 1975; May, 1985; Brown *et al*., 1990; Bellgrove *et al*., 1997; Arevalo *et al*., 2007; Bellgrove *et al*., 2010). For example, Kindig & Littler (1980) demonstrated that *Corallina officinalis* var. *chilensis* in South California showed equivalent or enhanced health indices, highest productivity and lowest moralities (amongst the species examined) when exposed to primary or secondary sewage

effluent. Little difference in productivity was noted in the chlorinated secondary effluent or pine oil disinfectant. However, specimens from unpolluted areas were less tolerant, suggesting physiological adaptation to sewage pollution (Kindig & Littler, 1980). Grazers in the biotope may benefit from increased availability of food resources, due to enhanced growth.

Atalah & Crowe (2010) added nutrients to rockpools. The experimental treatments do not directly relate to the pressure benchmark but indicate some general trends in sensitivity. The rockpools were occupied by a range of algae including encrusting corallines, turfs of *Mastocarpus stellatus*, *Chondrus crispus* and *Corallina officinalis* and green and red filamentous algae. Nitrogen and phosphorous enhancement was via the addition of fertilizers, as either 40 g/litre or 20 g/litre. The treatments were applied for seven months and experimental conditions were maintained every two weeks. Nutrients had no significant effect on the cover of crustose coralline algae or the cover of red turfing algae (Atalah & Crowe, 2010). However, the cover of green filamentous algae increased where grazers were removed (Atalah & Crowe, 2010). The study suggests that, although red algal turfs may be tolerant of eutrophication and may even benefit, biotope composition may alter due to the proliferation of fast-growing ephemeral algae.

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

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

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

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

Where the biotope occurs in tide-swept or wave exposed areas (Connor *et al*., 2004) water movements will disperse organic matter reducing the level of exposure. The key characterizing species *Corallina officinalis* has been noted to increase in abundance and may form extensive turfs within the vicinity of sewage outfalls and at intermediately polluted sites (Littler & Murray, 1975; May, 1985; Brown *et al*., 1990; Bellgrove *et al*.,1999, 2010). *Corallina elongata* and the crusting

coralline *Lithophyllum incrustans* were present at sites dominated by *Ulva* spp. in the Mediterranean exposed to high levels of organic pollution from domestic sewage (Arévalo *et al.*, 2007). In the Mediterranean Salas *et al.* (2006) note that the presence of *Sargassum* is an indicator of good water quality but no further information was provided. As turf-forming algae including the red algal turf and particularly *Corallina* spp. trap large amounts of sediment the turf is not considered sensitive to sedimentation. The turfs host a variety of associated species and deposit feeders amongst these would be able to consume inputs of organic matter.

Sensitivity assessment. Based on resistance to sedimentation, exposure to wave action, the presence of detrital consumers and the dominance of turfs in areas subject to sewage inputs, resistance is assessed as **'High'** and resilience as **'High'** (by default). The biotope is therefore considered to be **'Not sensitive'** to this pressure at the benchmark.

♟ Physical Pressures

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

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

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

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

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 & Airoldi, 2005). *Many species have specific preferences for substratum type. Corallina officinalis* shows optimal settlement on finely rough artificial substrata (0.5 - 1mm surface particle diameter). Although spores will settle and develop as crustose bases on smooth surfaces, fronds were only initiated on rough surfaces. *Corallina officinalis* settled on artificial substrata within one week in the field in summer months in New England (Harlin & Lindbergh 1977). However, in the laboratory fronds can grow from bases attached to smooth surfaces (Wiedeman pers comm. Previous MarLIN review) Similarly, tests with stone panels fixed to the sublittoral, mid-tide and high-tide levels of varying roughness found that *Ulva* species settle preferentially on smother, fine-grained substratum (chalk, mottled sandstone) and *Porphyra purpurea* on rougher, granulated substratum (limestone, granite, basaltic larvae) (Luther, 1976).

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

Sensitivity assessment. A change to a soft sedimentary habitat would remove the habitat for this biotope, while a change to an artificial substratum could also impact the development of this biotope as species may have settlement preferences for particular surface textures. Sheer artificial structures will be free draining and not offer pool habitats to support this biotope. Resistance is assessed as **'None'** and resilience as **'Very low'** as the change is considered to be permanent. Sensitivity is, therefore, assessed as **'High'.**

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

Not relevant to biotopes occurring on bedrock.

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

The species characterizing this biotope occur on the rock and therefore have no shelter from abrasion at the surface. Littler & Littler (1983) suggest that the basal crustose stage of *Corallina officinalis* is adaptive to resist sand scour and wave shearing (as well as physiological stressors such as desiccation and heating). The base is much tougher than the fronds shown by experiments that demonstrate that the base has nearly twice the mechanical resistance (measured by penetration) of fronds (Littler & Kauker, 1984).

In general, studies show that *Corallina* and other turf forming algae appear to be relatively resistant to single events and low levels of trampling. Brosnan & Crumrine (1994), for example, found that in experimentally trampled plots the cover of foliose and canopy forming species declined while turf forming algae were relatively resistant. Similarly, a comparison of rocky intertidal ledges that received different amounts of visitors in Dorset, England, found that *Corallina officinalis* and encrusting corallines were present on both heavily visited and less visited ledges suggesting that these species has some resistance to trampling (Pinn & Rodgers, 2005). Povey & Keough (1991) in Mornington Peninsula, Australia investigated the effects of sustained trampling on intertidal coralline algal mats where upright branching *Corallina* spp. formed a turf with other red algae with

sand and encrusting coralline algae between turfs. The experimental strips were 2 m long and 0.5 m wide. The percentage cover of upright *Corallina* spp. was significantly affected by 25 passages of a strip per day after 12 and 33 days. The algae appeared flattened and were shorter (1-2 cm high) compared with the low intensity and control plots (3-4 cm high). However low intensity trampling within a strip (2 passages/ day) did not significantly affect the Coralline turf. Fletcher and Frid (1996a; 1996b) 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.

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

Species associated with the coralline turf may be more sensitive. The limpets and littorinids that occur in low densities in this biotope have some protection from hard shells or plates but abrasion may damage and kill individuals or detach these. Removal of limpets may result in these being displaced to a less favourable habitat and injuries to foot muscles in limpets may prevent reattachment. Although limpets and littorinids may be able to repair shell damage, broken shells while healing will expose the individual to more risk of desiccation and predation. Evidence for the effects of abrasion is provided by a number of experimental studies on trampling (a source of abrasion) and on abrasion by wave thrown rocks and pebbles.

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

kicked limpet (out of 80) was broken and 2 (out of 80) limpets that were stepped on could not be relocated the following day (Povey & Keough, 1991). On the same shore, less than 5% of littorinids were crushed in single step experiments (Povey & Keough, 1991).

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

Sensitivity assessment. The impact of surface abrasion will depend on the footprint, duration and magnitude of the pressure. Based on evidence from the step experiments and the relative robustness of the encrusting corallines and *Corallina officinalis* turf and associated species, resistance, to a single abrasion event is assessed as **'Medium'** (loss of <25% cover/abundance) 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. Increased abrasion that altered the density of grazers may enhance the growth of red and green algae and may lead to changes in classification at the sub-biotope level.

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

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

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

Intertidal biotopes will only be exposed to this pressure when submerged during the tidal cycle and thus have limited exposure. Siltation, which may be associated with increased suspended solids and the subsequent deposition of these is assessed separately (see siltation pressures). In general, increased suspended particles reduce light penetration and increase scour and deposition. They may enhance food supply to filter or deposit feeders (where the particles are organic in origin) or decrease feeding efficiency (where the particles are inorganic and require greater filtration efforts).

Increases in the cover of sediment trapping, turf-forming algae at the expense of canopy-forming species have been observed worldwide in temperate systems and have been linked to increased suspended solids linked to human activities worldwide (Airoldi, 2003). *Corallina* species accumulate more sediment than any other alga (Hicks, 1985). Hence an increase in suspended sediment is likely to accumulate in the coralline turf. A significant increase may result in smothering (see above). An accumulation of sediment within the turf may attract more sediment dwelling interstitial invertebrates such as nematodes, harpacticoids and polychaetes, although in more wave exposed locations accumulation of sediment is likely to be minimal. Increased

suspended sediment may also result in increased scour, which may adversely affect foliose red algae, and interfere with settling spores and recruitment if the factor is coincident with their major reproductive period. However, coralline algae, especially the crustose forms are thought to be resistant of sediment scour (Littler & Kauker, 1984), and will probably not be adversely affected at the benchmark level. Therefore, an increase in suspended sediment may reduce the epiphytic species diversity in the immediacy, and adversely affect the cover of fleshy red algae and an intolerance of intermediate has been recorded. Recoverability is likely to be very high as species are likely to remain *in situ* from which recruitment can occur.

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

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 understorey on seaweed dominated shores. Therefore, a decrease in light intensity is unlikely to adversely affect the biotope. An increase in light intensity is unlikely to adversely affect the biotope as plants can acclimate to different light levels.

Sensitivity assessment. The exposure of biotope to suspended sediments in the water column will be limited to immersion periods allowing the suspended solids to settle (see siltation pressures). The biotope is considered to be 'Not sensitive' to a reduction in suspended solids, although this may reduce food supply to the barnacles and other filter feeders that occur in this biotope. An increase in suspended solids may lead to some sub-lethal abrasion of fronds however, evidence globally indicates that an increase in suspended solids favours the turf-forming algae that characterize this biotope (Airoldi, 2003). The encrusting corallines also seem to be tolerant. Resistance is, therefore, assessed as **'High'** and resilience as **'High'** (by default) so that the biotope is considered to be **'Not sensitive'**.

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

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 Airoldi, 2003). However, even the most tolerant of organisms would eventually suffer from inhibition and mortality following smothering although the thresholds for these effects have has not been identified (Airoldi, 2003). *Corallina officinalis* and others within the genus (e.g. *Corallina pinnatifolia* and *Corallina vancouveriensis*) are found on shores subject to high rates of sedimentation that are periodically disturbed by sand burial and scour (Stewart, 1989). Coralline turfs also trap sediments within the turf. The amount of sediment present and the associated fauna varies naturally depending on local conditions such as wave exposure (Dommasnes, 1969). On intertidal shores in southern California the amount of sediment trapped within turfs of *Corallina* spp. varied seasonally from < 5mm to >4.5 cm and was closely related to species composition and the structure of the turf. Airoldi (2003) identified a number of morphological, physiological and life history traits that conferred high levels of tolerance to sedimentation. Those shared by *Corallina* spp are the regeneration of upright fronds from a perennial basal crust

resistant to burial and scour, calcified thalli, apical meristems, large reproductive output, lateral vegetative growth and slow growth rates (Airoldi, 2003).

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

Other species within the biotope, particularly limpets and littorinids are considered more sensitive to sedimentation. Chandrasekara & Frid (1998) specifically tested the siltation tolerance of *Littorina littorea*. Approximately half of the test individuals could not regain the surface from 1cm of burial except in the most favourable conditions (low temperatures, high water, high silt when a majority (10 out of 15) of the test cohort surfaced. Field observations support the findings that *Littorina littorea* are generally unable to survive smothering. Albrecht & Reise (1994) observed a population of *Littorina littorea* in a sandy bay near the Sylt island in the North Sea. They found that the accretion of mud within *Fucus* strands and subsequent covering of *Littorina* by the sediment resulted in them suffocating and a significant reduction in their abundance. Field observations and laboratory experiments have highlighted the sensitivity of limpets to sediment deposition Airoldi & Hawkins (2007) tested the effects of different grain sizes and deposit thickness in laboratory experiments using *Patella vulgata*. At 1 and 2 mm thicknesses, fine sediments decreased grazing by 40 and 77 %. The addition of approximately 4 mm of fine sediment completely inhibited grazing. Limpets tried to escape the sediment but lost attachment and died after a few days (Airoldi & Hawkins, 2007) Observations on exposed and sheltered shores with patches of sediment around Plymouth in the south west of England confirmed that *Patella vulgata* abundances were higher where deposits were absent. The limpets were locally absent in plots with 50-65% sediment cover (Airoldi & Hawkins, 2007).

Early settlement stages are likely to be sensitive to siltation. Moss *et al.* (1973), for example, found that growth of zygotes of *Himanthalia elongata* was inhibited by a layer of silt 1-2 mm thick and that attachment on silt was insecure.

Atalah & Crowe (2010) added sediment to rockpools in controlled experiments that appear to be very similar to this biotope. 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 winkle *Littorina littorea* and the flat top shell *Gibbula umbilicalis*. Sediment treatment involved the addition of a mixture of coarse and fine sand of either 300 mg/cm^2/month or 600 mg/cm^2 every 15 days (the depth of sediment was not reported). The experimental treatments do not directly relate to the pressure benchmark but indicate some general trends in sensitivity. In the pools, the chronic addition of both levels of sediment led to a significant decrease in grazers and crustose coralline algae also decreased. Sedimentation had no significant effect on the cover of green filamentous algae (*Ulva* sp.) but led to an increase in the mean cover of red turfing algae (*Mastocarpus stellatus* and *Chondrus crispus* and *Corallina officinalis*) from 11.7% (±1.0 S.E.) in controls to 26.1% (±4.7 S.E.) in sedimented assemblages, but there were no differences between the two levels of sedimentation. The cover of red filamentous algae (*Ceramium* spp. *Gelidium* spp.) was also

significantly increased in the sedimentation experiments. The experimental results support the general trend of the greater sensitivity of grazers and encrusting corallines to sedimentation than turf-forming algae.

Sensitivity assessment. Where sediments are added to tide pools they may be removed rapidly in wave exposed environments where pools are flushed or they may remain in-situ increasing the level of exposure. These effects are site specific and will mediate the level of impact. Within the biotope the associated limpets are probably the most sensitive element, littorinids may also be negatively impacted but his will depend on the character of the deposit. Where grazing is reduced then the algal assemblage is likely to change. The encrusting corallines may be sensitive to sedimentation but the level of sensitivity is difficult to ascertain from the evidence base. The turf-forming species are generally tolerant of some sedimentation but the threshold in relation to the benchmark is not easily determined, especially as this biotope occurs in rockpools which may increase the exposure. The **encrusting corallines and grazers** are considered to have **'Low'** resistance to this pressure and **'Medium'** resilience, while the **algal turf** is considered to have **'Medium'** resistance and **'High'** resilience. The more precautionary assessment of 'Medium' sensitivity is recorded.

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

The available evidence for siltation pressures is outlined for the 'light' deposition pressure. At the pressure benchmark 'heavy deposition' represents a considerable thickness of deposit and may fill shallow pools. Complete burial of algal turf and encrusting corallines and associated animals would occur. Removal of the sediments by wave action and tidal currents would result in considerable scour. The effect of this pressure is likely to be mediated by the length of exposure to the deposit. Resistance is assessed as **'Low' to 'None'** as the impact is likely to be significant and would almost certainly result in the loss of grazers and a high proportion of the encrusting corallines. Resilience is assessed as **'Medium'** and sensitivity is assessed as **'Medium'.**

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

Not assessed

Electromagnetic changes	No evidence (NEv)	No evidence (NEv)	No evidence (NEv)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

No evidence.

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

Not relevant.

Introduction of light or shading	Low	High	Low
	Q: High A: Low C: High	Q: High A: High C: High	Q: High A: Low C: High

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

Sensitivity assessment. As the key structuring and characterizing 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 **'High'** (by default) resilience and, therefore, is **'Not sensitive'** to this pressure.

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

Barriers that reduce the degree of tidal excursion may alter larval supply to suitable habitats from source populations. Conversely, the presence of barriers may enhance local population supply by preventing the loss of larvae from enclosed habitats. Barriers and changes in tidal excursion are not considered relevant to the characterizing crusting corallines and *Corallina officinali*s 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. Other species associated with the biotope are widely distributed and produce large numbers of larvae capable of long distance transport and survival, resistance to this pressure is assessed as **'High'** and resilience as **'High'** (by default). This biotope is, therefore, considered to be **'Not sensitive'**.

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

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

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

Not relevant.

🦑 Biological Pressures

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

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

Introduction or spread of invasive non-indigenous species

Low   Very Low   High

Q: High A: Medium C: High   Q: Low A: NR C: NR   Q: Low A: Low C: Low

Within rockpools, temperature and salinity may be subject to rapid variation and these conditions will largely exclude species that are adapted to more stable, subtidal environments. Invasive non-indigenous species (INIS) that can alter habitats (ecological engineers), or out-compete native macroalgae for space and other resources such as light and nutrients, are the most likely species to negatively affect this biotope.

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

Sargassum muticum is a very successful invasive species. Space pre-emption by *Sargassum muticum* and shading may prevent further settlement of INIS until disturbance events create gaps for invasion. Where rockpools become colonized by *Sargassum muticum* and it is able to become established, the resultant biotope will change to LR.FLR.Rkp.Sar.

The red seaweed *Grateloupia turuturu* occurs on the lower shore in pools. No ecosystem impacts have been reported in Great Britain; however, this large, fast-growing seaweed may have the potential to displace native seaweed species and shade neighbouring species. In North America, this species is a major competitor of *Chondrus crispus* which provides an important winter food source for littorinids and other invertebrates. As *Grateloupia turuturu* dies-back in the winter, the displacement of other species may, therefore, affect grazers (Sweet, 2011g). In the Mediterranean crustose corallines and algal turfs facilitate attachment of *Caulerpa racemosa* by providing a more complex substratum than bare rock (Bulleri & Benedetti-Cecchi, 2008).

The tunicates *Didemnum vexillum* and *Asterocarpa humilis*, the hydroid *Schizoporella japonica* and the bryozoan *Watersipora subatra* (Bishop, 2012c, Bishop, 2015a and b; Wood, 2015) are currently only recorded from artificial hard substratum in the UK and it is not clear what their established range and impacts in the UK would be. *Didemnum vexillum* occurs in tide pools in other areas where

it has become established (Bishop, 2012c) and can have substantial effects on communities, similarly the tunicates *Corella eumyota* and *Botrylloides violaceus* can smother rock habitats (Bishop, 2011b and 2012b).

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

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

Sensitivity assessment. Little evidence was found to assess the impact of INIS on this biotope and much of the evidence comes from intertidal habitats in other countries. Replacement of red algal turfs by other similar species may lead to some subtle effects on local ecology but at low abundances, the biotope would still be recognisable from the description. However, colonization by *Sargassum muticum* is likely to result in loss of this biotope (LR.FLR.Rkp.Cor) and its replacement by LR.FLR.Rkp.Sar. Similarly, the conversion of this biotope to a *Magallana gigas* reef would present a significantly negative impact. Based on *Sargassum muticum* or *Magallana giga*s, resistance to this pressure is assessed as **'Low'**. The biotope will only recover if the INIS is removed, either through active management or natural processes. To recognise that recovery may be prolonged, resilience is assessed as **'Very low'** and sensitivity is, therefore, assessed as **'High'**.

Introduction of microbial pathogens

High	High	Not sensitive
Q: High A: High C: High	Q: High A: High C: High	Q: High A: High C: High

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

Other species associated with this biotope such as littorinids, patellid limpets and other algae also experience low levels of infestation by pathogens but mass-mortalities have not been recorded. For example, parasitism by trematodes may cause sterility in *Littorina littorea*. *Littorina littorea* is also parasitized by the boring polychaete, *Polydora ciliata* and *Cliona sp*, which weakens the shell and increases crab predation. Outbreaks of the shellfish pathogen *Martelia* spp. may cause widespread mortality of *Mytilus edulis* (Mainwaring *et al*., 2014) but populations within the UK have not been significantly impacted. No evidence was found for pathogens of *Mastocarpus stellatus* but Craigie & Correa (1996) described 'green spot' disease in *Chondrus crispus*, caused by the interaction of several biotic agents including fungi, bacteria, algal endophytes and grazers, and resulting in tissue necrosis. Correa & McLachlan (1992) infected *Chondrus crispus* with the green algal endophytes *Acrochaete operculata* and *Acrochaete heteroclada*. Infections resulted in detrimental effects on host performance, including slower growth, reduced carrageenan yield, reduced generation capacity and tissue damage. Stanley (1992) described the fungus *Lautita danica* being parasitic on cystocarpic *Chondrus crispus* and Molina (1986) was the first to report *Petersenia pollagaster*, a fungal invasive pathogen of cultivated *Chondrus crispus*. At usual levels of infestation in wild populations, these are not considered to lead to high levels of mortality.

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

Removal of target species

Low	High	Low
Q: High A: High C: High	Q: High A: High C: High	Q: High A: High C: High

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The sensitivity assessment for this pressure considers any biological/ecological

effects resulting from the removal of target species on this biotope. A number of species present in the biotope may be harvested recreationally or commercially. Seaweeds within the biotope can be harvested to produce compounds used in a variety of applications such as thickening and stabilizing agents in the food industry.

The key characterizing and structuring species *Corallina officinalis* is collected for medical purposes; the fronds are dried and converted to hydroxyapatite and used as bone forming material (Ewers *et al.*, 1987). Red and green algae may also be collected, *Chondrus crispus* is harvested commercially in Scotland and Ireland, the stipe is removed but the base is left intact to allow the algae to re-grow. *Palmaria palmata* and *Osmundea pinnatifida* are also collected by hand commercially and recreationally for consumption. The effect of harvesting *Chondrus crispus* has been best studied in Canada. Prior to 1980, the seaweed beds of Prince Edward Island were dominated by *Chondrus crispus* and the species was heavily exploited. The authors suggested that harvesting had brought about a shift in community structure following a marked increase in abundance of another red seaweed, *Furcellaria lumbricalis*, which is avoided by the commercial harvest with an associated decline in abundance of *Chondrus crispus* (Sharp *et al.*, 1993). Sharp *et al.* (1986) reported that the first drag rake harvest of the season, on a Nova Scotian *Chondrus crispus* bed, removed 11% of the fronds and 40% of the biomass. Efficiency declined as the harvesting season progressed. Chopin *et al.* (1988) noted that non-drag raked beds of *Chondrus crispus* in the Gulf of St Lawrence showed greater year-round carposporangial reproductive capacity than a drag raked bed. In the short-term, therefore, harvesting of *Chondrus crispus* may remove biomass and impair reproductive capacity, while in the long-term, it has the potential to alter community structure and change the dominant species. Removal of other associated algae such as *Palmaria palmata* and *Osmundea pinnatifida* will reduce cover of turf-forming red algae in this biotope. Garbary *et al.*, (2012) studied harvested and non-harvested shores in Nova Scotia, Canada containing stands of *Palmaria palmata*. They also conducted the experimental removal of *Palmaria palmata* and assessed simulated removal of *Palmaria palmata* by an experienced commercial harvester. Simulated commercial harvesting reduced cover of *Palmaria palmata* from 70% to 40%, although experimental removal on shores that were not usually harvested reduced cover to 20% (Garbary *et al.*, 2012).

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

Sensitivity assessment. The key characterizing species and a number of the associated species are harvested, this may alter the character of the biotope resulting in reclassification. Removal of *Corallina officinalis* and red and green algae will lead to changes in the character of the biotope but it is unlikely that selective targeted harvesting of these species would lead to biotope reclassification as other similar species would increase in abundance. Removal of the associated

limpet and littorinid grazers may allow red and green algae to increase in abundance and density. However, these algae may also be subject to harvesting limiting their dominance. Biotope resistance is assessed as **'Low'** as the species are readily harvested and removed, resilience is assessed as **'High'**, based on the regrowth of species from holdfasts and crustose bases with compensation between red and green algae. Sensitivity is, therefore, assessed as **'Low'**.

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

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The sensitivity assessment for this pressure considers any biological/ecological effects resulting from the removal of non-target species on this biotope. The biotope is characterized by epilithic algae that have no protection from removal by human activities that result in this pressure. Incidental removal of the key characterizing species and associated species would alter the character of the biotope. The biotope is characterized by *Corallina officinalis* and other associated species. The loss of the biological assemblage due to incidental removal as by-catch would, therefore, alter the character of the habitat and result in the loss of species richness. The ecological services such as primary production and the habitat provided by these species would also be lost.

Sensitivity assessment. Removal of a large percentage of the characterizing species would alter the character of the biotope, species richness and ecosystem function. Resistance is, therefore, assessed as **'Low'**. Resilience is assessed as **'High'** as the biotope is considered to recover rapidly where crustose bases, encrusting corallines and holdfasts remain. Sensitivity is, therefore, assessed as **'Low'**.

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