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Marine Information Network

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

Corallina officinalis, *Himanthalia elongata* and *Patella ulyssiponensis* on very exposed lower eulittoral rock

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

Dr Heidi Tillin & Dr Harvey Tyler-Walters

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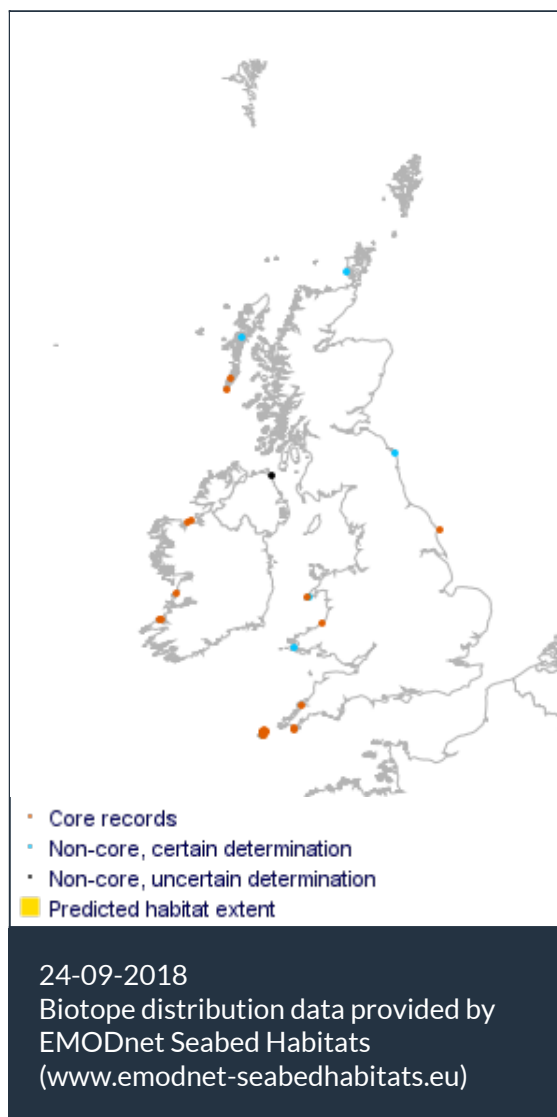
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Researched by Dr Heidi Tillin & Dr Harvey Tyler-Walters

Refereed by This information is not refereed.

Summary

☰ UK and Ireland classification

EUNIS 2008	A1.1222	<i>Corallina officinalis</i> , <i>Himanthalia elongata</i> and <i>Patella ulyssiponensis</i> on very exposed lower eulittoral rock
JNCC 2015	LR.HLR.FR.Coff.Puly	<i>Corallina officinalis</i> , <i>Himanthalia elongata</i> and <i>Patella ulyssiponensis</i> on very exposed lower eulittoral rock
JNCC 2004	LR.HLR.FR.Coff.Puly	<i>Corallina officinalis</i> , <i>Himanthalia elongata</i> and <i>Patella ulyssiponensis</i> on very exposed lower eulittoral rock
1997 Biotope		

🔍 Description

Very exposed to exposed lower eulittoral bedrock shores in the south-west can support a dense turf of the red seaweed *Corallina officinalis* found underneath the long erect fronds of the wrack *Himanthalia elongata*. The rock surface is pitted with the limpet *Patella ulyssiponensis*. Also found on

the bedrock is the barnacle *Chthamalus stellatus* or the limpet *Patella vulgata*, while numerous cracks and crevices provide shelter for anemones such as *Actinia equina* or the mussel *Mytilus edulis*. Other turf-forming red seaweeds include *Lomentaria articulata*, *Mastocarpus stellatus*, *Palmaria palmata*, *Gastroclonium ovatum*, *Ceramium* spp. and *Osmundea pinnatifida* which can be found along with the kelp *Laminaria digitata*. Foliose green seaweeds such as *Ulva intestinalis* and *Ulva lactuca* may also be present along with siphonous *Codium* spp. Sponges such as *Grantia compressa*, *Halichondria panicea* and *Hymeniacidon perleve* may be present in shaded areas. The brown seaweed *Bifurcaria bifurcata* and the barnacle *Balanus perforatus* may occur in the extreme south-west.

This community usually forms a distinct band just above the kelp zone (Ala; Ala.Ldig or Ldig). It can be found below the barnacle and *Patella vulgata* dominated biotopes (Cht; Sem or Sem.FvesR). There might be some fluctuations in the abundance of the individual species from year to year that revert this biotope into either the Coff.Coff or the Him biotopes. (Information from Connor *et al.*, 2004; JNCC, 2015).

↓ Depth range

Lower shore

Additional information

-

✓ Listed By

- none -

Further information sources

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Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

Corallina officinalis is the dominant characterizing species within this sub-biotope LR.HLR.FR.Coff.Puly and its similar variant sub-biotope LR.HLR.FR.Coff.Coff. *Corallina officinalis* forms a dense turf that provides substratum and refuges for a diverse epifauna. As the biotope characterization and many of the associated species are dependent on the presence of *Corallina officinalis* the sensitivity assessments specifically considers this species as both a key structuring and characterizing species. Other turf-forming algae such as *Lomentaria articulata*, *Mastocarpus stellatus*, *Palmaria palmata* and *Osmundea pinnatifida* occur in low abundances. The green seaweeds *Ulva intestinalis*, *Ulva lactuca* and *Cladophora rupestris* are present as well and assessments describe the sensitivity of the red and green species in general terms. *Himanthalia elongata* also occurs but in a similar abundance to the LR.HLR.FR.Him biotope, therefore, this species is considered specifically within the assessment where its sensitivity differs and it may come to dominate the biotope. Gastropods *Littorina littorea*, *Patella vulgata* and *Patella ulysiponensis* are significant grazers in the eulittoral zone and, by preferentially grazing on foliose red and green algae, structure the biotope allowing *Corralina* sp. to dominate. They are, therefore, included as important structural species. *Patella ulysiponensis* characterizes the variant biotope description and supports differentiation of the biotope from the very similar LR.HLR.FR.Coff.Coff. The sensitivity of this species to pressures is, therefore, highlighted. A number of invertebrates are present on the bedrock underneath the coralline turf, including the barnacle *Semibalanus balanoides*, the mussel *Mytilus edulis*, the sponges *Halichondria panicea* and *Hymeniacion perleve*, the anemone *Actinia equina*. These common rocky shore species contribute to species diversity and ecological function within the biotope but are not considered to be important structural or functional species and are only generally referred to within the assessments. Epiphytic grazers, such as amphipods, isopods and small gastropods probably keep the turf free of epiphytic algae and are important structural species. Due to lack of evidence the sensitivity of this group is considered only generally where the pressures may impact on this biotope. Temporal variation of the abundances of the characterizing species within this biotope may lead to biotope reversion between LR.HLR.FR.Coff.Coff, LR.HLR.FR.Coff.Puly and LR.HLR.FR.Him as these contain broadly similar species and occur in similar conditions (Connor *et al.*, 2004). The biotope assessments are largely considered applicable to the infralittoral biotope in the EUNIS classification A3.118.

Resilience and recovery rates of habitat

Where this biotope is impacted by pressures, recovery of the key structuring and characterizing species *Corallina officinalis* will require either regrowth from surviving holdfast or basal crusts or recolonization by propagules. The crustose holdfast or base is perennial and grows apically (continuous growth at tips), similar to encrusting corallines such as *Lithothamnium* 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 are an adaptation to resist grazing and desiccation whereas the fronds are adapted for higher primary productivity and reproduction. The basal crusts are tougher than the upright fronds (requiring a pressure of 94 g/mm² to penetrate, compared to 43 g/mm² respectively). Regeneration of the basal crusts provides a more rapid route to recovery than recolonization. Experiments in the intertidal in southern California found that areas scraped back to crusts recovered four times more rapidly than sterilised plots where the crusts were removed (Littler & Kauker, 1994).

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 & Johansen 1973). Similarly Blake & Maggs (2003) observed much higher growth rates of 2 mm/month over 6 months starting from September in *Corralina officinalis* grown in Strangford Lough (Northern Ireland) at 5 and 10 m depth, these rates are similar to those observed by Andrade & 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 lower 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, Littler & Kauker (1984) experimentally cleared plots and followed the recovery for 12 months. Some areas were scraped allowing the basal crusts to remain whereas others were completely sterilised (removal of all material and surfaces then scorched with a blow torch to remove bases). In scraped plots, up to 15% cover of *Corallina officinalis* fronds returned within 3 months after removal of fronds and all other epiflora/fauna (Littler & Kauker, 1984) while in sterilized plots (all basal crusts removed) appearance of articulated fronds occurred 6 months following clearance. At the end of the 12 month observation period, *Corallina officinalis* cover had increased to approximately 18% in plots where basal crusts remained and to approximately 10% in sterilised plots. Similarly, Bamber & Irving (1993) reported that new plants grew back in scraped transects within 12 months, although the resistant crustose bases were probably not removed.

Once established turfs of *Corallina* spp. can persist for a long time, surveys of rocky intertidal ledges at Hinkley point, Somerset in England have found that the patches mapped in the 1980s (Bamer & 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. Some potential mechanisms for inhibition of canopy-forming species are space pre-emption by turfs that prevent recruitment of taller algae (Perkol-Finkel & Airoidi, 2010, Kennelly, 1987) due to the coverage of suitable rock surfaces and the presence of sediments within the turf (Airoidi, 2003). Clearance experiments on rocky, intertidal shores in Southern California (Sousa, 1979) found that *Ulva* species which have a longer reproductive season could colonize cleared areas preventing the establishment of perennial red algae. However, grazing by crabs removed the green algae (Sousa, 1979), highlighting the potential importance of grazers, particularly littorinids, to the re-establishment of this biotope.

Recolonization of *Patella vulgata* on rocky shores is rapid as seen by the appearance of limpet spat six months after the *Torrey Canyon* oil spill reaching peak numbers 4-5 years after the spill. Similarly, after the *Torrey Canyon* oil spill, the entire populations of *Patella ulysiponensis* on certain beaches were wiped out by the uncontrolled use of dispersants but it took only 3-5 years for *Patella ulysiponensis* to return to population sizes and distributions found before the oil spill (Southward & Southward, 1978). In addition, following the creation of a new rocky shore in the Moray Firth, *Patella vulgata* was present in quadrats after 3 years (Terry & Sell, 1986). However, although recolonization was rapid on the oil-impacted shores, the alteration to the population structure (size and age class) persisted for about 15 years because of the complex cycles of

dominance (see below) involving limpets, barnacles and algae (Lewis & Bowman, 1975; Hawkins & Southward, 1992). Hence the establishment of fucoids if *Patella vulgata* and other grazers were absent may lead to the longer-term exclusion of this species.

Himanthalia elongata has a unique life history and growth pattern. The species has a biennial life cycle, reproducing once and then dying. *Himanthalia elongata* has a two stage morphology. A small button-like frond is first produced, from which large strap-like reproductive fronds are formed. The button stage is clubbed shaped at first and then develops into a button shape 2-3 cm in diameter, which is connected to the substrate by a holdfast and short stipe. Each button typically produces 2 strap-like reproductive fronds in autumn, although plants have been observed with 1 to 4 straps. Usually, germlings become visible on the shore in early March and form buttons with an average size of 10-25 mm by August. Those buttons which grow to 15 mm by November produce receptacles that autumn. The receptacles grow little in length during autumn and winter but increase rapidly between February and May. When the plants are fertile the straps become mottled with brown spots, each spot with a pale centre marking the opening to the conceptacle. The species invests 98% of the total biomass in reproductive rather than vegetative tissue (Brenchley *et al.*, 1996). Time of reproduction is strongly site dependent, probably due to water temperature. Population and age-structure studies suggest the plant is biennial although some plants grow vegetatively for two years before reproducing in the third year (Russell, 1990). Gamete dispersal is thought to be limited so recruitment from external populations is probably low. Early germling growth is probably strongly influenced by the presence of adults, or other foliose algae providing protection from desiccation, wave action and high irradiances, although shading probably limits growth rates of the germlings (Stengel *et al.*, 1999; Stengel pers. comm.).

Himanthalia elongata recruited to concrete blocks placed in the intertidal zone (within an existent population of *Himanthalia elongata* at Finavarra West Ireland) at an average level of 45 buttons per block (968 sq. cm in area) in March of the first year, dropping to only 4 or 5 buttons per block by early summer, but rising to 1500 buttons per block by March of the second year (Stengel *et al.*, 1999). The timing of the placement of blocks, when most gametes had been released, most likely contributed to the low recruitment observed in the first year (Stengel *et al.*, 1999). Survival and growth of buttons in West Ireland were higher in red algal turfs and lower on exposed rock so that the availability of suitable micro-habitats influences distribution (Stengel *et al.*, 1999). Where the canopy is entirely cleared recruitment and recovery may be prolonged. At Artedeo, northern Spain plots 30 cm² were cleared (using a paint scraper and wire brush) at different tidal heights (Viejo, 2009). At a low tidal level where *Himanthalia elongata* dominated with *Fucus vesiculosus* present, cleared plots recovered more slowly than those higher in the intertidal. The canopy forming species had recovered four years after disturbance but differences in understory algae persisted (Viejo, 2009).

Resilience assessment. No direct evidence was found for the age of individual *Corallina* crusts, the longevity of turfs, or the time to recover from basal crusts or sterilised plots to a full dense cover. New crustose bases may recruit and develop quickly but the formation of new fronds from these bases and recovery of original cover may take longer. 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 2 years. Presumably, as crusts can grow in all directions percentage cover is not a linear function and that gap closure would speed up with greater cover. 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. The ephemeral green algae associated with the biotope are opportunist colonizers of gaps and would be expected to recover within a year. Limpets and littorinids could recover through migration but where populations are removed over a larger area recolonization by larvae would be required. Recruitment through larvae may be episodic and recovery to former population structure may require >2 years. Recruitment and survival of *Himanthalia elongata* are enhanced by the presence of adults due to low dispersal rates and the requirement for shelter. Resilience is probably 'High' (within 2 years) where resistance is 'High' or 'Medium' (the removal of <25 % of the adults within the biotope is predicted). Where the biotope is more extensively impacted (i.e. resistance is 'Low' or 'None'), recovery of the *Himanthalia elongata* canopy will probably be 'Medium' (2-10 years).

Therefore, the resilience of the biotope is assessed as 'High' where resistance is 'High' (no significant impact) or 'Medium' (where <25 % of *Corallina officinalis* or *Himanthalia elongata* fronds are removed and bases remain) based on regrowth from the basal crusts and vegetative growth from surrounding turfs and repair, migration or recolonization of associated species. Where resistance is 'Low' or 'None' then resilience is assessed as 'Medium' (between 2 -10 years) but towards the lower end of that range for *Corallina officinalis* and the associated species. 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.

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

Hydrological Pressures

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

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). 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 of exposure to temperatures between 0°C and 28°C. Latham (2008) investigated the effects of temperature stress on *Corallina officinalis* through laboratory tests on samples collected in the Autumn in Devon, England from rock pools. Samples were kept at 1°C for three days and then exposed to temperatures of 5°C, 15°C, 20°C, 25°C and 30°C (the normal range of temperature experienced was suggested to be between 5 and 15°C). At 35°C, the *Corallina* was completely bleached after 3 days with a sample kept at 30°C beginning to bleach. After 7 days (the end of the experiment) the sample kept at 30°C was partially bleached. Samples kept at 5, 15, 20 and 25°C showed little change in chemicals produced in reaction to thermal stress and no bleaching suggesting the temperatures in that range had not induced stress reactions.

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.

Himanthalia elongata has a cold-temperate distribution. Its southern distribution limit is northern Spain (Martínez *et al.*, 2015) and in that area, its range has been contracting, possibly due to increased temperatures (Duarte *et al.*, 2013). An examination of survey records from 1974- 2010 correlated with summer and winter surface temperatures (Yesson *et al.*, 2015) suggest that in the UK *Himanthalia elongata* is negatively correlated with winter temperatures (e.g. abundance is greater where winters are colder), the abundance of *Himanthalia elongata* could, therefore, decline due to chronic or acute increases in winter temperatures. Experiments were conducted to determine the physiological threshold tolerances to temperature of *Himanthalia elongata* collected from shores at Redondela (Ria de Vigo, Spain) and Moledo (northern Portugal). Fronds were kept in tanks and maintained at one of a range (from 8.3°C to 29.8°C) of 12 temperatures for 6 weeks with 20 replicates for each temperature. Mortality and frond growth (weight to nearest 0.1g) were measured weekly (Martínez *et al.*, 2015). A marked growth decline occurred at 18°C; this temperature was also the threshold where the probability of survival was 0.5, e.g. 50% of plants at this temperature were likely to die. These findings were supported by field observation, as the species was absent from locations with average August sea surface temperatures higher than 19°C (Martínez *et al.*, 2015). Increased temperatures may affect reproduction and survival of early stages. *Himanthalia elongata* plants began gamete release on the west coast of Ireland in June at two sites where water temperatures were 16-18°C (Stengel *et al.*, 1999). Gamete release may be triggered by temperature or by photoperiod as the release also coincides with longer day length. Moss *et al.* (1973) tested the effects of different levels of light intensity and temperature on the growth of early stages of *Himanthalia elongata*. These laboratory experiments indicated that gamete release could occur at a range of temperatures between 10 and 20°C. Zygotes kept at 22°C and 25°C failed to germinate at all light intensities (total darkness to 6000 Lux).

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 rock pools, where water and air temperatures are greatly elevated on hot days. Empirical evidence for thermal tolerance to anthropogenic increases in temperature is provided by the effects of heated effluents on rocky shore communities in Maine, USA. *Ascophyllum* and *Fucus* were eliminated from a rocky shore heated to 27-30°C by a power station whilst *Ulva intestinalis* (as *Enteromorpha intestinalis*) increased significantly near the outfall (Vadas *et al.*, 1976). Barnacles, *Semibalanus balanoides*, limpets, *Patella vulgata* and littorinids 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 37.3°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. Hiscock *et al.* (2004), suggest that a 1-2°C increase in temperature could increase the reproductive success of *Patella ulyssiponensis* potentially resulting in a northward expansion of the range.

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 (1984) 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. Similarly, *Himanthalia elongata* and the other characteristic algae are widely distributed in the British Isles and probably not sensitive to change in temperature at the benchmark level. The sensitivity of the biotope is based on the key characterizing *Corallina* turf and *Himanthalia* 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 is assessed as 'Not sensitive' at the benchmark level. It should be noted that the timing of acute 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* and *Semibalanus balanoides* to longer-term, broad-scale perturbations would potentially be greater due to effects on reproduction but these changes may lead to species replacements (by *Patella depressa* or *Patella ulyssiponensis* and *Chthamalus* spp.) but are not considered to significantly affect the character of the biotope. An increase in *Patella ulyssiponensis* may lead to the increase in records of this biotopes due to the conversion of similar biotopes (e.g. LR.HLR.FR.Coff.Coff or LR.HLR.FR.Him) to this biotope (Coff.Puly).

Temperature decrease
(local)

High

Q: High A: High C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: High C: High

Many intertidal species are tolerant of freezing conditions as they are exposed to extremes of low air temperatures during periods of emersion. They must also be able to cope with sharp temperature fluctuations over a short period of time during the tidal cycle. In winter air

temperatures are colder than the sea, conversely in summer air temperatures are much warmer than the sea. Species that occur in the intertidal are therefore generally adapted to tolerate a range of temperatures, with the width of the thermal niche positively correlated with the height of the shore (Davenport & Davenport, 2005).

Under extremely low temperatures, components of the community demonstrate tolerance. Lüning (1990) reported that *Corallina officinalis* from Helgoland survived 0°C when exposed for one week. New Zealand specimens were found to tolerate -4°C (Frazer *et al.*, 1988). Lüning (1990) suggested that most littoral algal species were tolerant of cold and freezing. For example, the photosynthetic rate of *Chondrus crispus* recovered after 3hrs at -20°C but not after 6 hrs (Dudgeon *et al.*, 1990). The photosynthetic rate of *Mastocarpus stellatus* higher on the shore fully recovered from 24 hrs at -20°C. *Himanthalia elongata* has a cold-temperate distribution, its southern distribution limit is northern Spain (Martínez *et al.*, 2015) and in that area, its range has been contracting, possibly due to increased temperatures (Duarte *et al.*, 2013). An examination of survey records from 1974-2010 correlated with summer and winter surface temperatures suggest that in the UK *Himanthalia elongata* is negatively correlated with winter temperatures (e.g. abundance is greater where winters are colder), suggesting that in the UK lower temperatures are beneficial for this species (Yesson *et al.*, 2015). Experiments were conducted to determine the physiological threshold tolerances to temperature of *Himanthalia elongata* collected from shores at Redondela (Ria de Vigo, Spain) and Moledo (northern Portugal). Fronds were kept in tanks and maintained at one of a range of 12 temperatures (8.3°C to 29.8°C) for 6 weeks with 20 replicates for each temperature. Mortality and frond growth (weight to nearest 0.1g) were measured weekly (Martínez *et al.*, 2015). Over the course of the experiment 16°C appeared to be the optimal temperature for growth. However, plants maintained at the lowest temperature 8°C still grew at similar rates to those kept at 10°C and 12°C. No further evidence was found to suggest sensitivity to lower temperatures.

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. *Patella ulyssiponensis* may be sensitive to long-term decreases in temperature (Hiscock *et al.*, 2004).

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**' at the benchmark level. 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. A long-term decrease in temperature may lead to conversion this biotope characterized by *Patella ulyssiponensis* to a similar sub-biotope (e.g. LR.HLR.FR.Coff.Coff or FR.Him).

Salinity increase (local)

Low

Q: Low A: NR C: NR

Medium

Q: High A: Low C: Medium

Medium

Q: Low A: Low C: Low

Local populations may be acclimated to the prevailing salinity regime and may, therefore, exhibit different tolerances to other populations subject to different salinity conditions and therefore caution should be used when inferring tolerances from populations in different regions. This biotope is found in full (30-35 ppt) salinity (Connor *et al.*, 2004). Biotopes found in the intertidal will naturally experience fluctuations in salinity where evaporation increases salinity and inputs of rainwater expose individuals to freshwater. Species found in the intertidal are therefore likely to have some form of behavioural or physiological adaptations to changes in salinity. The characterizing species *Corallina officinalis* and *Patella ulyssiponensis* are found in tide pools 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.

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). In the laboratory, *Semibalanus balanoides* was found to tolerate salinities between 12 and 50 psu (Foster, 1970). Young *Littorina littorea* inhabit rock pools where salinity may increase above 35 psu. Thus, the associated species may be able to tolerate some increase in salinity. *Mytilus edulis* is found in a wide range of salinities from variable salinity areas and mussels in rock pools are likely to experience hypersaline conditions on hot days. Newell (1979) recorded salinities as high as 42 psu in intertidal rock pools, suggesting that *Mytilus edulis* can tolerate high salinities. Wright & Reed (1985) exposed *Himanthalia elongata* samples to hypersaline media (51 ppt, 68 ppt or 102 ppt) for 3 days. The plants were kept at 15°C in seawater for less than 48 hours prior to the experiment. Compared to control plants maintained at natural salinities (34 ppt) photosynthesis of plants maintained at 51 ppt decreased by approximately 20% compared with control plants after 1 day and 42% after 3 days. Greater changes occurred at more extreme salinities: plants maintained for 3 days at 102 ppt photosynthesised as <20% of the rate of control plants (Wright & Reed, 1985). *Himanthalia elongata* may tolerate a short-term increase (for perhaps a week or more) but this will affect photosynthesis and over longer time periods this is likely to lead to mortality.

Sensitivity assessment. No direct evidence was found to assess sensitivity to this pressure. Although some increases in salinity may be tolerated by the associated species present these are generally short-term and mitigated during tidal inundation. This biotope is considered, based on the distribution of *Corallina officinalis* and *Himanthalia elongata* on the mid to lower shore to be sensitive to a persistent increase in salinity to >40 ppt. Resistance is therefore assessed as '**Low**' and recovery as '**Medium**' (following restoration of usual salinity). Sensitivity is, therefore, assessed as '**Medium**'.

Salinity decrease (local)

Low

Q: Medium A: Low C: Low

Medium

Q: High A: Low C: Medium

Medium

Q: Low A: Low C: Low

Biotores found in the intertidal will naturally experience fluctuations in salinity where evaporation increases salinity and inputs of rainwater expose individuals to freshwater. Species found in the intertidal are therefore likely to have some form of behavioural or physiological adaptations to changes in salinity. As this biotope is present in full salinity, the assessed change at the pressure benchmark is a reduction in salinity to a 'reduced' regime (18-30 ppt).

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

Wright & Reed (1985) exposed *Himanthalia elongata* samples to hyposaline media (2 ppt, 8 ppt or 17 ppt) for 3 days. The plants were kept at 15°C in seawater for less than 48 hours prior to the experiment. Compared to control plants maintained at natural salinities (34 ppt) photosynthesis of plants maintained at 17 ppt decreased by approximately 30% compared with control plants after 1 day and 50% after 3 days. Greater changes occurred at more extreme salinities: plants maintained for 3 days at 2 ppt photosynthesised at <30% of the rate of control plants (Wright & Reed, 1985). *Himanthalia elongata* may tolerate a short-term increase (for perhaps a week or more) but this will affect photosynthesis and over longer time periods this is likely to lead to mortality. The *Himanthalia elongata* maintained in extreme hyposaline medium, 2 and 8 ‰ for longer than 1 day, developed bladder-like structures around the thallus (Wright & Reed, 1985). Experiments in laboratory culture have also shown that the fertilized eggs of *Himanthalia elongata* are very sensitive to even a slight drop in salinity. The percentage that germinate starts to fall as soon as the salinity falls and by the time the salinity is at 50% of normal seawater (value not given but assumed to be approximately 17 ppt) no germination takes place. Low tolerance for reductions in salinity may explain the absence of this species from river estuaries and from rocks adjacent to them (Moss *et al.*, 1973).

Some of the species associated with this biotope have a high tolerance for this pressure based on their occurrence in estuaries. 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, 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 6.5psu (Riisgård *et al.*, 1993).

Sensitivity assessment. Although some daily changes in salinity may be experienced these will be mitigated during tidal inundation. Prolonged reduction in salinity, e.g. from full 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. In addition, a reduction in salinity for one year may result in the loss of a proportion of the *Corallina* turf and the abundance of *Himantalia*, based on the *Corallina officinalis* distribution and the evidence of Kinne

(1971), together with the experimental evidence on *Himantalia*. Resistance is, therefore, assessed as 'Low' and recovery as 'Medium' (following restoration of usual salinity) so that sensitivity is assessed as 'Medium'.

Water flow (tidal current) changes (local)

High

Q: High A: Low C: NR

High

Q: High A: High C: High

Not sensitive

Q: High A: Low C: Low

The biotope (LR.HLR.FR.Coff) is found in a range of flow rates from 'moderately strong' (0.5-1.5 m/s) to very 'weak' negligible) (Connor *et al.*, 2004; Dommasnes, 1969) although not information on the individual sub-biotopes (i.e LR.HLR.FR.Coff.Puly) was available. 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. Additionally, an increase to stronger flows may inhibit settlement of spores and remove adults or germlings. However, *Corallina officinalis* has a compact, turf-forming growth form that reduces water flow through turbulence and friction and is probably resistant to displacement by an increase in water flow. Changes in water flow at the pressure benchmark may result in increased or decreased sediment deposition, these are not considered to alter the character of the biotope but may alter species richness of the small invertebrates associated with the turf. In addition, the biotope is found in high energy wave exposed habitats where wave mediated water flow is probably the most important factor in structuring the biotope.

Sensitivity assessment. The biotope is found across a range of flow rates, mid-range populations are considered to have 'High' resistance to a change in water flow at the pressure benchmark (although see sediment supply caveats). Resilience is assessed as 'High', by default, and the biotope is considered 'Not sensitive'.

Emergence regime changes

Low

Q: High A: Low C: Medium

Medium

Q: High A: Low C: Medium

Medium

Q: High A: Low C: Medium

Emergence regime is a key factor structuring this (and other) intertidal biotopes although it should be noted that *Corallina officinalis* may occur at a range of shore heights depending on local conditions such as the degree of wave action (Dommasnes, 1969), shore topography, run-off and degree of shelter from canopy-forming macroalgae. Increased emergence may reduce habitat suitability for characterizing and associated species through greater exposure to desiccation and reduced feeding opportunities for the barnacles, anemones, sponges and *Mytilus edulis* which feed when immersed. Changes in emergence may, therefore, lead to species replacement and the development of a biotope, more typical of the changed shore level may develop.

Corallina officinalis is sensitive to desiccation (Dommasnes, 1969) and generally not found on open rock unless protected by algal canopies or where the surfaces are damp or wet. At Hinkley Point (Somerset, England), for example, seawater run-off from deep pools high in the intertidal supports dense turfs of *Corallina* spp. lower on the shore (Bamber & Irving, 1993). Fronds are highly intolerant of desiccation and do not recover from a 15% water loss, which might occur within 40-45 minutes during a spring tide in summer (Wiedemann, 1994). Bleached corallines were observed 15 months after the 1964 Alaska earthquake which elevated areas in Prince William Sound by 10 m. Similarly, increased exposure to air caused by upward movement of 15 cm due to nuclear tests at Amchitka Island, Alaska adversely affected *Corallina pilulifera* (Johansen, 1974). During an unusually hot summer, Hawkins & Hartnoll (1985) observed damaged *Corallina officinalis* and other red algae. Littler & Littler, (1984) suggest that the basal crustose stage is

adaptive, allowing individuals to survive periods of physical stress as well as physiological stress such as desiccation and heating. The basal crust stage may persist for extended periods with frond regrowth occurring when conditions are favourable.

Himanthalia elongata may physiologically tolerate an increase in the period of emergence because it has been found to grow 2 m vertically further up the shore in the absence of limpets (Southward & Southward, 1978). Moss (1969) found that when *Himanthalia elongata* was kept out of water for some time e.g. during low tides, the oospheres shed on the surface of the receptacles are unable to escape from their mucilaginous envelope and so do not get fertilized. Gametes are, therefore, likely to be discharged under water (Moss, 1969) and changes in emergence are likely to reduce reproductive success. Therefore, an increase in the period of emergence would probably result in a depression of the species' upper limit on the shore.

Mobile epifauna are likely to relocate to more suitable habitats. Species such as *Patella vulgata* and *Littorina littorea* that are found throughout the intertidal zone are adapted to tolerate desiccation to some extent. For example, littorinids can seal the shell using the operculum while limpets clamped tightly to rock will reduce water loss. *Patella ulysiponensis* is generally restricted to the lower shore although it may inhabit tide pools on the upper shore (Delaney *et al.*, 1998). The green algae are also resistant to this pressure (although it may be bleached at higher shore levels during periods of high temperature) and are found throughout the intertidal including the high shore levels which may not be inundated every day. A significant, long-term, increase in emergence is therefore likely to lead to the replacement of this biotope with one more typical of the changed conditions dominated by limpets, barnacles and mussels or green algae for example.

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

Sensitivity assessment. Emergence is a key factor structuring the distribution of on the shore, resistance to **increased emergence** is assessed as '**Low**' as *Corallina officinalis* and associated red algae are intolerant of desiccation but basal crusts may allow individuals to persist in conditions that are unfavourable to frond development until the emergence regime is re-established. Resilience is assessed as '**Medium**' and sensitivity is therefore assessed as '**Medium**'. Pre-emption of space by *Corallina officinalis* and other red algae may reduce the establishment of lower shore species including kelps, resistance is therefore assessed as '**Medium**' to **decreased emergence** and recovery as '**Medium**' so that sensitivity is assessed as '**Medium**'. The more precautionary assessment for increased emergence is presented in the table.

Wave exposure changes (local)

High

Q: High A: Low C: NR

High

Q: High A: High C: High

Not sensitive

Q: High A: Low C: Low

This biotope is recorded from locations that range from very exposed to wave exposed (Connor *et al.*, 2004), while Dommasnes (1969) recorded coralline turfs from very wave sheltered areas in Norway. *Himanthalia elongata* has been observed at both wave exposed and semi-exposed sites in West Ireland (Stengel *et al.*, 1999). Survival and growth of *Himanthalia elongata* buttons were greater in algal turfs (as in this biotope) which was suggested to result from protection from wave action and desiccation (Stengel pers comm, cited in Stengel *et al.*, 1999). The morphology of *Himanthalia elongata* plants may alter depending on the degree of wave exposure. Stengel (pers comm, reported in Stengel *et al.*, 1999), found that at more wave exposed sites plants were smaller

and had narrower receptacles. This presumably reduces the drag forces on the plant and reduces levels of breakage and detachment.

The degree of wave exposure influences wave height, as in more exposed areas with a longer fetch, waves would be predicted to be higher. As this biotope occurs across a range of exposures, this was therefore considered to indicate, by proxy, that biotopes in the middle of the wave exposure range would tolerate either an increase or decrease in significant wave height at the pressure benchmark. It should be noted that amounts of sediment accumulated within the turf and the associated fauna are influenced by the prevailing conditions but the biotope is still recognisable as a coralline turf.

Sensitivity assessment. The biotope is found across a range of wave exposures, mid-range populations are considered to have '**High**' resistance to a change in significant wave height at the pressure benchmark. Resilience is assessed as '**High**', by default, and the biotope is considered '**Not sensitive**'.

Chemical Pressures

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

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

Contamination by non-synthetic chemicals, at levels greater than the pressure benchmark, may adversely impact the biotope. Little information was found concerning the effects of heavy metals on turf forming and encrusting coralline algae. However, Bryan (1984) suggested that the general order for heavy metal toxicity in seaweeds is: organic Hg > inorganic Hg > Cu > Ag > Zn > Cd > Pb. Most of the information available suggests that the associated 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) 10-100 µg/l and cadmium (Cd) 0.25-5 µg/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
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This pressure is **Not assessed** but evidence is presented where available.

Contamination by non-synthetic chemicals, at levels greater than the pressure benchmark, may adversely impact the biotope. 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).

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 by synthetic chemicals, at levels greater than the pressure benchmark, may adversely impact the biotope. Smith (1968) reported that oil and detergent dispersants from the *Torrey Canyon* spill affected high water plants of *Corallina officinalis* more than low shore plants and some plants were protected in deep pools. In areas of heavy spraying, however, *Corallina officinalis* was killed (Smith, 1968). Regrowth of fronds had begun within two months after spraying ceased (Smith, 1968). O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil or dispersant contamination, possibly due to the susceptibility of phycoerythrins to destruction. They also reported that red algae are effective indicators of detergent damage since they undergo colour changes when exposed to 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. Intertidal populations 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)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

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

Introduction of other substances

Not Assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

This pressure is **Not assessed**.

De-oxygenation

High

Q: Low A: NR C: NR

High

Q: High A: High C: High

Not sensitive

Q: Low A: Low C: Low

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 *Corallina* turfs or algal 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). *Semibalanus balanoides* can respire anaerobically, so they can tolerate some reduction in oxygen concentration (Newell, 1979). When placed in wet nitrogen, where oxygen stress is maximal and desiccation stress is low, *Semibalanus balanoides* have a mean survival time of 5 days (Barnes *et al.*, 1963). Limpets can 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 *Corallina*, brown and other red algal turfs was found. As the biotope will only be exposed to this pressure when emerged and respiration will occur in air, biotope resistance was assessed as 'High' and resilience as 'High' (no effect to recover from), resulting in a sensitivity of 'Not sensitive'.

Nutrient enrichment

High

Q: High A: Medium C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: Medium C: High

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 (Belgrove *et al.*, 2010; Littler & Murray, 1975; May, 1985; Brown *et al.*, 1990; Belgrove *et al.*, 1997). For example, Kindig & Littler (1980) demonstrated that *Corallina officinalis* var. *chilensis* in South California showed equivalent or enhanced health indices, highest productivity and lowest mortalities (amongst the species examined) when exposed to primary or secondary sewage effluent. Grazers in the biotope may

benefit from increased availability of food resources, due to enhanced growth.

Atalah & Crowe (2010) added nutrients to rockpools 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*. Nitrogen and phosphorous enhancement was via the addition of fertilisers, as either 40 g/litre or 20 g/litre. The treatments were applied for seven months and experimental conditions were maintained every two weeks. The experimental treatments do not directly relate to the pressure benchmark but indicate some general trends in sensitivity. Nutrients had no significant effect on the cover of *Corallina officinalis*. The cover of green filamentous algae was significantly increased both by reduced grazing and increased nutrients, although the effect size was synergistically magnified by the combined effect of grazer removal and nutrients. Nutrient enrichment caused an absolute increase in the average cover of green filamentous algae of 19% (± 3.9 S.E.) respect to the control treatments while the cover of red turfing algae was not affected by nutrient addition (Atalah & Crowe, 2010)

Sensitivity assessment. The pressure benchmark is relatively protective and may represent a reduced level of nutrient enrichment in previously polluted areas. Due to the tolerance of high levels of nutrient input demonstrated generally e.g. Belgrove *et al.* (2010) and Atalah & Crowe (2010), resistance to this pressure is assessed as '**High**' and resilience as '**High**' so that the biotope is assessed as '**Not sensitive**'. No evidence was found for the characterizing species *Himanthalia elongata*. Where *Corallina* dominated biotopes have replaced canopy forming species in enriched areas it is not clear whether a change to the benchmark would lead to a shift in biotope type. Once established the presence of *Corallina* spp. and other turf forming species may limit recruitment by taller species (Belgrove *et al.*, 2010). No evidence was found to support an assessment of this indirect effect and it is not presented.

Organic enrichment

High

Q: Low A: NR C: NR

High

Q: High A: High C: High

Not sensitive

Q: Low A: Low C: Low

No direct evidence was found to assess this pressure. Organic enrichment may lead to eutrophication with adverse environmental effects including deoxygenation, algal blooms and changes in community structure (see nutrient enrichment and de-oxygenation). Where the biotopes occur 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 (Belgrove *et al.*, 2010; Littler & Murray, 1975; May, 1985; Brown *et al.*, 1990). As turf-forming algae *Corallina* spp. trap large amounts of sediment and are therefore 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. Cabral-Oliveira *et al.* (2014), found higher abundances of juvenile *Patella* sp. and lower abundances of adults closer to sewage inputs, Cabral-Oliveira *et al.* (2014) suggested the structure of these populations was due to increased competition closer to the sewage outfalls. No evidence was found for the characterizing species, *Himanthalia elongata*.

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

A Physical Pressures

	Resistance	Resilience	Sensitivity
Physical loss (to land or freshwater habitat)	None	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

This biotope is characterized by the hard rock substratum to which the characterizing coralline turf and associated species such as red, brown and green algae, barnacles, limpets, and anemones can firmly attach. A change to a sedimentary substratum would significantly alter the character of the biotope and would lead to the development of a biological assemblage more typical of the changed conditions. A change to an artificial substratum could also impact the development of this biotope as species may have settlement preferences for particular surface textures. Artificial hard substratum may also differ in other characteristics from natural hard substratum, so that replacement of natural surfaces with artificial may lead to changes in the biotope through changes in species composition, richness and diversity (Green *et al.*, 2012; Firth *et al.*, 2014) or the presence of non-native species (Bulleri & Airoidi, 2005). *Corallina officinalis* shows optimal settlement on finely rough artificial substrata (0.5 - 1 mm surface particle diameter). Although spores will settle and develop as crustose bases on smooth surfaces, fronds were only initiated on rough surfaces. *Corallina officinalis* settled on artificial substrata within one week in the field in summer months in New England (Harlin & Lindbergh 1977). However, in the laboratory fronds can grow from bases attached to smooth surfaces (Wiedeman pers comm.). Similarly, tests with stone panels fixed to the sublittoral, mid-tide and high-tide levels of varying roughness found that *Ulva* species settle preferentially on smoother, fine-grained substratum (chalk, mottled sandstone) and *Porphyra purpurea* on rougher, granulated substratum (limestone, granite, basaltic larvae) (Luther, 1976). Moss *et al.* (1973) surveyed shores in the north east of England and recorded the substrata types where *Himanthalia elongata* occurred. Populations occurred on a variety of substrata including quartz dolomite, coal measure sandstone, limestone and millstone grit. Horizontal ledges of magnesian limestone were not colonized as it was too friable and easily eroded to allow firm attachment. *Himanthalia elongata* was absent from outcrops that were frequently silted where silts were mobile but it could colonize mats of sediment trapping red algae particularly *Rhodochorton* spp. (Moss *et al.*, 1973).

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, 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: Low C: Medium	Q: High A: Low C: Medium

The species characterizing this biotope occur on the rock and therefore have no shelter from abrasion at the surface. Littler & Littler (1984) suggest that the basal crustose stage of *Corallina officinalis* is adapted 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). No direct evidence was found to assess abrasion impacts on the key characterizing species *Himanthalia elongata*.

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* were present on both heavily visited and less visited ledges suggesting that this 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.

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 three 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.

Species associated with the coralline turf may be more sensitive. Soft-bodied species such as anemones are likely to be damaged or removed by abrasion, although anemones and sponges may repair and fragments may regrow. No evidence was found for the sensitivity of the small invertebrates associated with the coralline turf but abrasion could displace and damage these. The barnacles, limpets and littorinids that occur in low densities in this biotope, have some protection from hard shells or plates but abrasion may damage and kill individuals or detach these. All removed barnacles would be expected to die as there is no mechanism for these to reattach. Removal of limpets and barnacles may result in these being displaced to a less favourable habitat and injuries to foot muscles in limpets may prevent reattachment. Although limpets and littorinids may be able to repair shell damage, broken shells while healing will expose the individual to more risk of desiccation and predation. Evidence for the effects of abrasion is provided by a number of experimental studies on trampling (a source of abrasion) and on abrasion by wave thrown rocks and pebbles.

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

Shanks & Wright (1986), found that even small pebbles (<6 cm) that were thrown by wave action in Southern California shores could create patches in aggregations of the barnacle, *Chthamalus fissus*, and could smash owl limpets (*Lottia gigantea*). Average, estimated survivorship of limpets at a wave exposed site, with many loose cobbles and pebbles allowing greater levels of abrasion was 40% lower than at a sheltered site. Severe storms were observed to lead to 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).

Ulva spp. fronds are very thin and could be torn and damaged and individuals may be removed from the substratum, altering the biotope through changes in abundance and biomass. *Ulva* spp. cannot repair damage or reattach but torn fronds could still photosynthesise and produce gametes. Tearing and cutting of the fronds has been shown to stimulate gamete production and damaged plants would still be able to grow and reproduce. *Cladophora* spp. have a relatively tough thallus (Dodds & Gudder, 1992) but no direct evidence was found for resistance to abrasion. In Kimmeridge Bay in Southern England, Pinn & Rodgers (2005) found that the abundance of *Cladophora rupestris* was lower at a more heavily visited and trampled site.

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

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 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: Medium C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: Medium 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. Young stages of *Himanthalia elongata* were found to be very intolerance of

resultant siltation (Moss *et al.*, 1973), hence the impact of increased suspended sediment would depend on the time of year. If increased siltation occurred from June to December, when gametes are released, the population would be highly intolerant because zygotes cannot grow on silt (Moss *et al.*, 1973).

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 understory on seaweed dominated shores. Experiments have shown that *Ulva* is a shade tolerant genus and can compensate for reduced irradiance by increasing chlorophyll concentration and light absorption at low light levels. *Ulva* spp. were able to survive over two months in darkness and to begin photosynthesising immediately when returned to the light (Vermaat & Sand-Jensen, 1987). Limited shading from suspended sediments is therefore not considered to negatively affect this genus. Therefore, a decrease in light intensity is unlikely to adversely affect the biotope. An increase in light intensity is unlikely to adversely affect the biotope as plants can acclimate to different light levels.

Sensitivity assessment. The exposure of biotope to suspended sediments in the water column will be limited to immersion periods, and wave action will reduce accumulation. The biotope is considered to be 'Not sensitive' to a reduction in suspended solids, although this may reduce food supply to the barnacles and other filter and deposit 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). No evidence was found to assess the sensitivity of *Himanthalia elongata*, however, buttons can slough off sediments and the thallus is tough so unlikely to be abraded or covered by settling sediments. Therefore, resistance is assessed as '**High**' and resilience as '**High**' (by default) so that the biotope is considered to be '**Not sensitive**'. An increase in suspended solids above the pressure benchmark may result in a change in species composition with an increase in species seen in very turbid, silty environments e.g. *Ahnfeltia plicata*, *Rhodothamniella floridula*, *Polyides rotunda* and *Furcellaria lumbricalis*.

Smothering and siltation rate changes (light)

High

Q: High A: High C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: High C: High

Increased abundance of algal turfs worldwide has been linked to sediment perturbations although not all the pathways and mechanisms of these effects are clear (see review by 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 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. Airoidi (2003) identified a number of morphological, physiological and life history traits that conferred high levels of tolerance to sedimentation. Those shared by *Corallina* spp are the regeneration of upright fronds from a perennial basal crust resistant to burial and scour, calcified thalli, apical meristems, large reproductive outputs, lateral vegetative growth and slow growth rates (Airoidi, 2003). Experimental deposition of sand on coralline turfs and maintained at 3 cm or 6 cm for one month via daily top-ups did not remove the turfs but did lead to rapid (within 1 hours changes in the invertebrate species as highly mobile species moved away from the turf with later colonisation by sand adapted species (Huff & Jarett, 2007). The community had recovered one month after sand deposition ceased (Huff & Jarett, 2007).

Atalah & Crowe (2010) added sediment and nutrients to rockpools. The rock pools 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/cm²/month or 600 mg/cm² every 15 days. The treatments were applied for seven months and experimental conditions were maintained every two weeks. The experimental treatments do not directly relate to the pressure benchmark but indicate some general trends in sensitivity. In the pools, the chronic addition of both levels of sediment led to a significant increase in the cover of *Corallina officinalis*. 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.), but there were no differences between the two levels of sedimentation. The abundance of the limpet *Patella ulyssiponensis* was significantly reduced by sedimentation. The average abundance of limpets in pools with high levels of sediment added was significantly lower ($P < 0.05$, mean 1.4 ind/144 cm² ± 0.25 S.E.) than in pools with ambient sediment loading (mean 2.7 ind/144 cm² ± 0.3 S.E.) (Atalah & Crowe, 2010).

Observations and experiments indicate that *Ulva* spp. have relatively high tolerances for the stresses induced by burial (darkness, hypoxia and exposure to sulphides) Vermaat & Sand-Jensen, 1987; Corradi et al., (2006; Kamermans et al., (1998). *Ulva lactuca* is a dominant species on sand-affected rocky shores in New Hampshire (Daly & Mathieson, 1977) although Littler et al., (1983) suggest that *Ulva* sp., are present in areas periodically subject to sand deposition not because they are able to withstand burial but because they are able to rapidly colonise sand-scoured areas. *Ulva* spp. have, however, been reported to form turfs that trap sediments (Airoidi, 2003, references therein) suggesting that resistance to chronic rather than acute siltation events may be higher.

The associated species, *Patella vulgata* and *Littorina* spp. are likely to be negatively affected by siltation (Airoidi & Hawkins, 2007; Chandrasekara & Frid, 1998; Albrecht & Reise, 1994). Experiments have shown that the addition of even thin layers of sediment (approximately 4 mm) inhibit grazing and result in loss of attachment and death after a few days Airoidi & Hawkins (2007). The laboratory experiments are supported by observations on exposed and sheltered shores with patches of sediment around Plymouth in the south west of England as *Patella vulgata* abundances were higher where deposits were absent (Airoidi & Hawkins (2007). Littler et al. (1983) found that another limpet species, *Lottia gigantea* on southern Californian shores was restricted to refuges from sand burial on shores subject to periodic inundation by sands.

In general, propagules, early post-settlement stages and juveniles suffer severe stress and mortality from sediments (Vadas *et al.*, 1992; Airoidi, 2003). Moss *et al.* (1973) found that the growth of zygotes of *Himanthalia elongata* was inhibited by a layer of silt 1-2 mm thick and that attachment on silt was insecure. However, Stengel *et al.* (1999) found *Himanthalia elongata* at Finavarra (West Ireland) growing on flat limestone under shallow drifting sand. Intermittent exposure to silt and coarser sediments may, therefore, be tolerated by adult plants.

Sensitivity assessment. The *Corallina officinalis* and algal turf that characterizes this biotope probably has a 'High' resistance to siltation at the pressure benchmark based on Airoidi (2003). The associated species within the biotope have higher sensitivities. The loss of grazing species could reduce species richness and may allow some growth of ephemeral red and green algae. The different siltation resistances of the red turf-forming algae and *Patella ulyssiponensis* (Atalah & Crowe, 2010) suggest that siltation events could alter the biotope classification between the two sub-biotopes LR.HLR.FR.Coff.Coff and LR.HLR.FR.Coff.Puly and result in the loss of this biotope LR.HLR.FR.Coff.Puly. However, in this 'high energy' (HLR) habitat the deposit of 5 cm of sediment is unlikely to last for more than one tidal cycle. Therefore, resistance is assessed as '**High**', resilience as '**High**' and sensitivity assessed as '**Not sensitive**' at the benchmark level.

Smothering and siltation rate changes (heavy)

Low

Q: Low A: NR C: NR

Medium

Q: High A: Low C: Medium

Medium

Q: Low A: Low C: Low

No evidence was found to assess this pressure at the benchmark. A deposit at the pressure benchmark would cover all species with a thick layer of fine materials. Species associated with this biotope such as limpets and littorinids would not be able to escape and would likely suffer mortality. The tolerance of *Corallina officinalis* would be mediated by the length of time the deposit remained in place. The coralline turf and the red and green algae would be covered with sediment. Removal of the sediments by wave action and tidal currents would result in considerable scour. Moss *et al.* (1973), found that the growth of zygotes of *Himanthalia elongata* was inhibited by a layer of silt 1-2 mm thick and that attachment on silt was insecure. However, Stengel *et al.* (1999) found *Himanthalia elongata* at Finavarra (West Ireland) growing on flat limestone under shallow drifting sand. Intermittent exposure to silt and coarser sediments may, therefore, be tolerated by adult plants.

Field observations and laboratory experiments have highlighted the sensitivity of limpets to sediment deposition (Airoidi & Hawkins, 2007) tested the effects of different grain sizes and deposit thickness in laboratory experiments using *Patella vulgata*. Sediments were added as a 'fine' rain to achieve deposit thicknesses of approximately 1mm, 2 mm, and 4 mm in controlled experiments and grazing and mortality observed over 8-12 days. Limpets were more sensitive to sediments with a higher fraction of fines (67% silt) than coarse (58% sand). Coarse sediments of thicknesses approximately 1, 2 and 4 mm decreased grazing activity by 35, 45 and 50 % respectively. 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 (Airoidi & Hawkins, 2007). Observations on exposed and sheltered shores with patches of sediment around Plymouth in the south-west of England found that *Patella vulgata* abundances were higher where deposits were absent. The limpets were locally absent in plots with 50-65% sediment cover (Airoidi & Hawkins, 2007). Littler *et al.* (1983) found that another limpet species, *Lottia gigantea* on southern Californian shores was restricted to refuges from sand burial on shores subject to periodic inundation by sands.

Sensitivity assessment. Sensitivity to this pressure will be mediated by site-specific hydrodynamic conditions and the footprint of the impact. Where a large area is covered sediments may be shifted by wave and tides rather than removed. However, mortality will depend on the duration of smothering, where wave action rapidly mobilises and removes fine sediments, survival may be much greater. Even small deposits of sediments are likely to result in local removal of limpets. Resistance is assessed as '**Low**' 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 and associated algae. Resilience is assessed as '**Medium**' and sensitivity is assessed as '**Medium**'.

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

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

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

Introduction of light or shading	High Q: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High
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Corallina officinalis are shade tolerant algae, often occurring under a macroalgal canopy that reduces light penetration. In areas of higher light levels, the fronds may be lighter in colour due to bleaching (Colhart & Johansen, 1973). Other red algae in the biotope are flexible with regard to light levels. Canopy removal experiments in a rocky subtidal habitat in Nova Scotia, Canada by Schmidt & Scheibling (2007) did not find a shift in understorey macroalgal turfs (dominated by *Corallina officinalis*, *Chondrus crispus* and *Mastocarpus stellatus*) to more light-adapted species over 18 months. *Corallina officinalis* may be overgrown by epiphytes, especially during summer.

Moss *et al.* (1973) tested the effects of different levels of light intensity on the growth of early stages of *Himanthalia elongata*. Zygotes were plated and grown under light levels varying from darkness to 6000 Lux at three temperatures; 5, 10 and 20°C. Germination was measured after 7 days and growth after 1 month. In total darkness, a small proportion of zygotes germinated at 10 and 20°C (5-17 % and 0-6% respectively). At 5°C and 20°C germination rates were similar across all light intensities, the highest germination rates were achieved at the highest light intensity at 10°C (40-91%). Maximum growth occurred at 10°C and light intensities between 1272 and 5936 Lux (Moss *et al.*, 1973)

Sensitivity assessment. *Himanthalia elongata* shows maximal growth at a range of light temperatures and other structuring and characterizing species colonize a broad range of light environments from intertidal to deeper subtidal and shaded understorey habitats the biotope is considered to have '**High**' resistance and, by default, '**High**' resilience and, therefore, is '**Not**

sensitive' to this pressure.

Barrier to species movement

High

Q: Low A: NR C: NR

High

Q: High A: High C: High

Not sensitive

Q: Low A: Low C: Low

Barriers that reduce the degree of tidal excursion may alter larval supply to suitable habitats from source populations. Conversely, the presence of barriers may enhance local population supply by preventing the loss of larvae from enclosed habitats. Barriers and changes in tidal excursion are not considered relevant to the characterizing *Corallina officinalis* as species dispersal is limited by the rapid rate of settlement and vegetative growth from bases rather than reliance on recruitment from outside of populations. 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)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

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

Visual disturbance

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant.

Biological Pressures

Resistance

Resilience

Sensitivity

Genetic modification & translocation of indigenous species

No evidence (NEv)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

The characterizing species and other common rocky shores species within the biotope, with the exception of *Mytilus edulis* which occurs in low densities, are not subject to translocation or cultivation. No information was found on current production of *Mastocarpus stellatus*, *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.

Commercial cultivation of *Mytilus edulis* involves the collection of juvenile mussel 'seed' or spat (newly settled juveniles ca 1-2 cm in length) from wild populations, with subsequent transportation around the UK for re-laying in suitable habitats. As the seed is harvested from wild populations from various locations the gene pool will not necessarily be decreased by translocations. Movement of mussel seed has the potential to transport pathogens and non-native species (see sensitivity assessments for *Mytilus edulis* bed biotopes). A review by Svåsand *et al.* (2007) concluded that there was a lack of evidence distinguishing between different *Mytilus*

edulis populations to accurately assess the impacts of hybridisation with the congener *Mytilus galloprovincialis* and in particular how the gene flow may be affected by aquaculture. Therefore, it cannot be confirmed whether farming will have an impact on the genetics of wild individuals beyond a potential for increased hybridization.

Sensitivity assessment. No direct evidence was found regarding the potential for negative impacts of translocated mussel seed on wild *Mytilus edulis* populations. While it is possible that translocation of mussel seed could lead to gene flow between cultivated beds and local wild populations, there is currently no evidence to assess the impact (Svåsand *et al.*, 2007).

Introduction or spread of invasive non-indigenous species

High

Q: Low A: NR C: NR

High

Q: High A: High C: High

Not sensitive

Q: Low A: Low C: Low

The first records of the INIS *Watersipora subtorquata* in German coastal waters of the North Sea arose from individuals attached to drifting or stranded *Himanthalia elongata* that probably drifted from the English Channel 200 miles away (Kuhlenkamp & Kind, 2013). These records indicate that *Himanthalia elongata* can be colonized by this species. Although no evidence for negative effects has been reported. *Codium fragile* subsp. *tormentosoides* (now renamed as *Codium fragile fragile*) and the red seaweed *Heterosiphonia japonica* may have overlapping habitat requirements but neither have so far been recorded in nuisance densities (Sweet, 2011j). *Corallina officinalis* was the dominant species comprising 78-80% of the turf biomass beneath a canopy of the invasive *Codium fragile* ssp. *tomentosoides* on subtidal rocky shores in Nova Scotia, while *Chondrus crispus* and *Mastocarpus stellatus* comprised 18% (Schmidt & Scheibling, 2007). The biomass of *Corallina officinalis* was similar to those under a canopy of the native *Laminaria* species on the same shore (*Laminaria longicuris* and *Laminaria digitata*), suggesting little negative effect.

Wireweed, *Sargassum muticum*, grows best on sheltered shores and in rockpools (Sewell, 2011c) and the wave exposed habitats where this biotope occurs may not be suitable for establishment. The red seaweeds *Heterosiphonia japonica* and *Neosiphonia harveyi* may also occur in this biotope but again no impacts have been reported. The red seaweed *Grateloupia turuturu* occurs on the lower shore in pools. No ecosystem impacts have been reported in Great Britain; however, this large, fast-growing seaweed may have the potential to displace native seaweed species and shade neighbouring species. In North America, this species is a major competitor of *Chondrus crispus* which provides an important winter food source for littorinids and other invertebrates. As *Grateloupia turuturu* dies-back in the winter, the displacement of other species may, therefore, affect grazers (Sweet, 2011g).

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 furoid 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).

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.

The Australasian barnacle *Austrominius* (previously *Elminius*) *modestus* was introduced to British waters on ships during the second world war. However, its overall effect on the dynamics of rocky shores has been small as *Austrominius modestus* has simply replaced some individuals of a group of co-occurring barnacles (Raffaelli & Hawkins, 1999). Although present, monitoring indicates it has not outnumbered native barnacles in the Isle of Cumbrae (Gallagher *et al.*, 2015) it may dominate in estuaries where it is more tolerant of lower salinities than *Semibalanus balanoides* (Gomes-Filho *et al.*, 2010). The degree of wave exposure experienced by his biotope may limit colonization by *Austrominius modestus* which tends to be present in more sheltered biotopes.

Sensitivity assessment. Overall, there is little evidence of this biotope being adversely affected by non-native species. 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. Therefore, resistance is assessed as '**High**', and resilience as '**High**' (by default), and the biotope is considered to be '**Not sensitive**'. The conversion of this biotope to a *Magallana gigas* reef would present a significantly negative impact. However, there is little evidence of *Magallana gigas* developing a reef in wave exposed conditions, and the presence of an algal turf (e.g. of furoids) may prevent settlement. However, the evidence is lacking at present.

Introduction of microbial pathogens **High**

Q: Low A: NR C: NR

High

Q: High A: High C: High

Not sensitive

Q: Low A: Low C: Low

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 Rhodophycota, 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). 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.

The fronds of *Himanthalia elongata* frequently bear algal epiphytes and endophytes and a number of marine fungi but more rarely the parasite *Halosaccocolax kjellmanii* Lund (Guiry). Galls are produced by nematodes, copepods and bacteria (Irvine, 1983). The detrimental effects (if any) of such organisms are not known. The fungal pathogen, *Petersenia palmaria* n. sp (Oomycetes) which infects *Palmaria mollis*, does not affect the red algae *Palmaria palmata* (Van der Meer & Pueschel, 1985) which occurs in his biotope. Other species associated with this biotope such as littorinids, patellid limpets and other algae experience low levels of infestation by pathogens but mass-mortalities have not been recorded.

Sensitivity assessment. Based on the available evidence this biotope is considered to have 'High' resistance and hence 'High' resilience and is classed as 'Not sensitive' at the pressure benchmark.

Removal of target species

Low

Q: Low A: NR C: NR

Medium

Q: High A: Low C: Medium

Medium

Q: Low A: Low C: Low

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The sensitivity assessment for this pressure considers any biological/ecological effects resulting from the removal of target species on this biotope. 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). It is also sold as a powder for use in the cosmetic industry. Some species present in the biotope may also be targeted. The blue mussel *Mytilus edulis* is too small and patchy in this biotope to be targeted for commercial harvesting. However, some, unregulated recreational hand-gathering of this species and limpets, *Patella* spp., may occur. *Littorina littorea* may be targeted by commercial or recreational harvesters.

Himanthalia elongata is harvested in the UK and Ireland for use as food, food products and cosmetics and pharmaceuticals (www.seaweedindustry.com; Stengel *et al.*, 1999). The red algae *Mastocarpus stellatus* and *Chondrus crispus* are both 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. As the key characterizing and structuring species extensive removal of *Mastocarpus stellatus* and *Chondrus crispus* would alter the character of the biotope. 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. Recently, there has been a marked increase in abundance of another red seaweed, *Furcellaria lumbricalis*, which is not harvested, and an associated decline in abundance of *Chondrus crispus* (Sharp *et al.*, 1993). The authors suggested that harvesting has brought about the shift in community structure. 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. *Palmaria palmata* (known as dulse) is harvested from the wild for human consumption both commercially and recreationally. Garbary *et al.* (2012) studied harvested and non-harvested shores in Nova Scotia, Canada containing stands of *Palmaria*

palmata. They also conducted an 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 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).

Limpets may also be subject to harvesting. *Patella ulyssiponensis* and *Patella vulgata* are key characterizing and structuring species within this biotope. *Patella vulgata* grazing can control the character of the shore by grazing algae and newly settled barnacle larvae. Even a small, localised temporary absence of limpets (Southward, 1956; Southward, 1964; Hawkins, 1981; Hawkins *et al.*, 1983) can alter the biological assemblage. Significant limpet kills resulting from the widespread use of dispersants after the *Torrey Canyon* oil spill dramatically altered rocky shore communities. The flesh of *Patella ulyssiponensis* is highly prized in the Azores and Azorean communities in the USA and, in 1985, was the sixth most important fishery in the Azores (Martins *et al.*, 1987; Corte-Real *et al.*, 2000). Azorean stocks of *Patella ulyssiponensis* began to decline in the 1970s when snorkel diving became the main means of collection. The fishery was stable as long as recruitment remained high and only individuals 4 cm long were taken so that the limpets matured and bred before extraction. On some of the central islands of the Azores, individuals as small as 2 cm were being taken and the population was in decline because recruitment from outlying populations was low (Martins *et al.*, 1987). A ban on limpet extraction in these areas probably saved these populations of *Patella ulyssiponensis*.

Sensitivity assessment. Collection of the key characterizing species would significantly alter the character and structure of the biotope and result in the loss of species inhabiting the turf. Collection 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. The resistance of this biotope to targeted harvesting of characterizing and associated species is '**Low**' as the species are all relatively large, conspicuous and easily collected. Resilience is assessed '**Medium**' and sensitivity is assessed as '**Medium**'.

Removal of non-target species

Low

Q: Low A: NR C: NR

Medium

Q: High A: Low C: Medium

Medium

Q: Low A: Low C: Low

Incidental removal of the key characterizing species and associated species would alter the character of the biotope. The biotope is characterized by dense turfs of *Corallina officinalis*, these provide habitat and attachment surfaces for epiphytic species and where these trap sediments

also provide a habitat for associated species. The loss of the turf 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 and secondary production provided by these species would also be lost.

Sensitivity assessment. Removal of a large percentage of the characterizing species resulting in bare rock would alter the character of the biotope, species richness and ecosystem function. Resistance is, therefore, assessed as '**Low**' and recovery as '**Medium**' so that sensitivity is assessed as '**Medium**'.

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