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

Yellow and grey lichens on supralittoral rock

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

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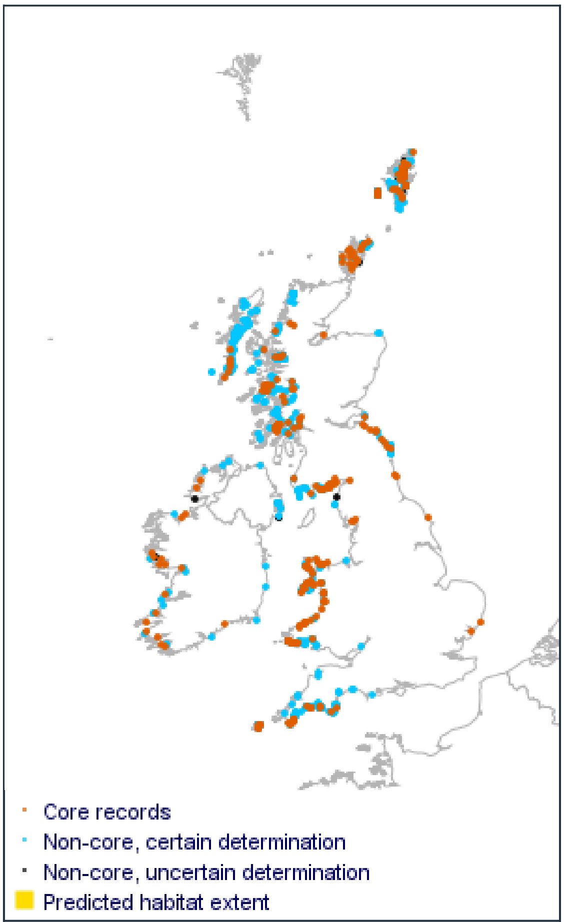
Yellow and grey lichens on supralittoral rock at Millport, Isle of Cumbrae.
Photographer: Anon.



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

Researched by Dr Harvey Tyler-Walters **Refereed by** This information is not refereed.

Summary

UK and Ireland classification

EUNIS 2008	B3.111	Yellow and grey lichens on supralittoral rock
JNCC 2015	LR.FLR.Lic.YG	Yellow and grey lichens on supralittoral rock
JNCC 2004	LR.FLR.Lic.YG	Yellow and grey lichens on supralittoral rock
1997 Biotope	LR.L.YG	Yellow and grey lichens on supralittoral rock

Description

Vertical to gently sloping bedrock and stable boulders in the supralittoral (or splash zone) of the majority of rocky shores are typically characterized by a diverse maritime community of yellow and grey lichens, such as *Xanthoria parietina*, *Caloplaca marina*, *Lecanora atra* and *Ramalina* spp. The black lichen *Verrucaria maura* is also present, but usually in lower abundance than in the littoral fringe zone. In wave exposed conditions, where the effects of sea-spray extend further up the shore, the lichens generally form a wide and distinct band. This band then becomes less distinct as wave exposure decreases, and in sheltered locations, cobbles and pebbles may also support the biotope. Pools, damp pits and crevices in the rock are occasionally occupied by winkles such as *Littorina saxatilis* and halacarid mites may also be present.

This biotope is usually found at the top of the shore, immediately above a zone of the black lichen *Verrucaria maura* (LR.FLR.Lic.Ver; Ver.Ver; Ver.B). Above the band of LR.FLR.Lic.YG, and occasionally in crevices in the rock alongside the lichens, terrestrial plants such as the thrift Armeria maritima and other angiosperms often occur. In sheltered areas the transition from YG to Ver.Ver is often indistinct and a mixed zone of YG and Ver.Ver may occur. In estuaries, this biotope is often restricted to artificial substrata such as sea defences. (Information from Connor *et al.*, 2004).

Depth range

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Additional information

Little information was found on the ecology of maritime lichen communities. The information that follows was based on reviews by Fletcher (1973a, 1973b, & 1980) and general lichen ecology by Seaward (1977), Dobson (2000) and Nash (2008). The author would welcome comments from lichenologists.

Listed By

- none -

Further information sources

Search on:

G G G JNCC

Habitat review

Ecology

Ecological and functional relationships

The supralittoral lies above high water level of spring tides and is influenced by wave wash, splash and sea spray. The mobile fauna varies with the tidal submergence and wave exposure with marine intertidal species further up the shore at high tide and mobile species of terrestrial origin foraging down the shore as the tide recedes only to return to the top of the shore as the tide returns (e.g. spiders). Other species of terrestrial origin, notably mites (acarids), and some spring tails (Collumbola) and bristle-tails (Thysanura) seek refuge is cracks and crevices at high tide.

- Lichens are a symbiotic association of a fungus and microalgae and therefore provide primary productivity as well as refuge.
- Lichens are fed on by fungivorous Cryptostigmata and other acarid mites e.g. *Hyadesia fusca*, *Phauloppia lucorum*, *Mycolates parmetiae* and *Ameronothrus maculatus* (Colloff, 1983; Pugh & King, 1988; Bücking, 1998; Gilbert 2000), and potentially by some lichen dwelling tardigrades (Gerson & Seaward, 1977) and the bristle tail *Petrobius maritimus* (Joosse, 1976), while rotifers have been reported to consume lichen ascospores (Gerson & Seaward, 1977).
- Gastropods such as *Littorina saxatilis* and *Melarhaphe neritoides* graze littoral lichens such as *Verrucaria maura* and *Lichina pygmaea* and could potentially graze other lichens in the lower supralittoral.
- Detritus may accumulate within lichens, in pits or crevices and is fed on by detritivores such as acarid mites, tardigrades, and nematodes (Roth & Brown, 1976; Gerson & Seaward, 1977; Pugh & King, 1988).
- Predators include acarid mites, some tardigrades (e.g. *Milnesium tardigradum*), spring tails (Collumbola) such as *Anurida maritima*, centipedes of terrestrial or intertidal origin (e.g. *Strigamia maritima* that may take isopods, amphipods and periwinkles), anthocorid bugs (e.g. *Temnostethus pusillus* that feeds on mites), and terrestrial or maritime spiders and pseudo-scorpions (Roth & Brown, 1976; Pugh & King, 1985a, 1988; Gilbert, 2000).
- Scavengers include the sea slater (*Ligia oceanica*) in the lower supralittoral (Nicholls, 1931) and acarid mites (Pugh & King, 1985a; 1988)
- The invertebrate fauna probably provides a food source for predatory birds, such as the rock pipit (*Anthus spinoletta*), while other vertebrates such as rabbits, goats, and sheep may graze foliose or fructicose lichens directly (Fletcher, 1980; Dobson, 2000; Gilbert 2000).

Seasonal and longer term change

Fletcher (1980) suggested that cloudy days during the year or the winter climate were most conducive to growth, although it was noted that lichen growth rates varied widely between different locations, between different species and even between different thalli of the same species at the same site. The colour of some thalli may change with season, for example *Xanthoria parietina* becomes greener in winter or shaded conditions (Fletcher, 1980). In the winter months, the lichens at the bottom of the supralittoral may be overgrown by ephemeral green algae (e.g. *Ulva* sp., filamentous green algae such as *Ulothrix* sp.). On areas subject to bird-manuring (e.g. bird perches) littoral fringe lichens may be overgrown in the winter months by *Prasiola stipitata*. At the top of the supralittoral, lichens may be shaded by the growth of terrestrial plants in summer.

Summer annuals probably have little effect on the lichens, however, on sheltered sites, shading by large plants favour a more terrestrial lichen flora (Fletcher, 1980).

Jones *et al.* (1974) suggested that lichens were slow growing and long lived with estimated ages of 100 years or more. Therefore, changes in lichen communities was slow unless caused by pollution (Jones *et al.*, 1974). James & Syratt (1986) reported that changes in the lichen community or loss of lichens in Sullom Voe could be attributed to direct competition between lichens (overgrowth), gastropod grazing (a minor effect), physical abrasion from wind, trampling or animal rubbing, human interference (e.g. building) or bird manuring. However, the supralittoral lichen communities were relatively stable at most sites monitored between 1978 to 1986 (James & Syratt, 1986).

Habitat structure and complexity

Several zones and their characteristic flora and fauna have been identified within the lichen dominated supralittoral of rocky shores. The complexity of the habitat is primarily dependent on the presence of crevices, recesses, ledges and rock pools in the rocky substrata, together with the additional niches and refuges provided by the lichen flora itself.

Supralittoral zonation
The supralittoral zone occurs above the upper littoral fringe, characterized by *Verrucaria maura*, *Lichina pygmaea* and small littorinids, and below the terrestrial zone characterized by inland lichens such as species of *Parmelia* and maritime plants (e.g. *Armeria maritima* and *Festuca rubra*). The following supralittoral zones have been identified (Fletcher, 1973a&b, 1980; Dobson, 2000).

- The mesic-supralittoral, lying above the littoral fringe, receiving heavy spray and occasional submergence of the lower part during extreme spring tides. The mesic-supralittoral is characterized by encrusting cracked or areolate (composed of islands of tissue) lichens, or lichens with lobose margins. For example, the orange crustose *Caloplaca marina* and black foliose *Lichina confinis* form the lower part of the zone with grey-white *Lecanora* sp. above, although the species composition varies and may be composed of several species of *Caloplaca* and *Lecanora* and other lichens.
- The mesic-supralittoral is dominated by orange *Caloplaca marina* and white *Lecanora actophila* on sunny shores, forming the characteristic 'orange belt', but on shaded shores *Caloplaca marina* cover is reduced, being replaced by sparse *Caloplaca thallincola* and more common white and grey *Lecanora* species so that the zone becomes more 'leaden-grey' in colour.
- A submesic-supralittoral zone occurs above the mesic-supralittoral and is characterized by the regular occurrence of *Xanthoria parietina*. This zone is not always present, being rare or absent on shaded shores and diffuse or sparse on sunny shores exposed to wave or wind action where the zone is restricted to crevices and shallow fissures. However, *Xanthoria parietina* may dominate the supralittoral in areas affected by heavy bird manuring.
- The xeric-supralittoral (the 'grey' zone) receiving light spray and exposed to a harsh regime of wetting and drying. The xeric-supralittoral is characterized by cracked crustose or narrow lobed, substrata hugging foliose or narrow lobed shrubby lichens including *Ramalina siliquosa*, *Tephromela atra var. atra*, *Rhizocarpon constrictum*, *Parmelia prolixa*, *Anaptychia runicata* (as *fusca*), *Lecanora* sp., *Ochrolechia parella*, and many other species overlapping with the mesic or submesic below or the terrestrial zones above (Fletcher, 1973a&b; 1980).
- The species composition of the xeric-supralittoral is variable, depending on local

topography, patterns of seawater deposition, runoff and drought.
- Damp rock crevices and fissures allow lichens of lower zones (e.g. *Verrucaria* spp.) to penetrate higher on the shore, while heavy bird-manuring may allow submesic communities to dominate. Crevices and shaded fissures may support unique flora e.g. the *Sclerophytetum circumscriptae* association (James *et al*., 1977).
- The top of the supralittoral is delimited by a zone of halophilic and halophobic lichens of more terrestrial origin, that integrates into coastal or maritime vegetation, e.g. *Armeria maritima* dominated communities (Rodwell, 2000).
- High shore rockpools may occur at the bottom of the supralittoral and support distinct communities (e.g. LR.G). Ledges or large fissures that accumulate debris and soil may be colonized by plants and their associated fauna (see Rodwell, 2000). Rock pool and vascular plant communities are not considered further here.

Factors affecting zonation

The species composition, growth form and diversity of the lichen flora and hence the complexity of the habitat for lichens and other fauna varies between and within the above zones. The extent and height and of each zone is dependent on substratum texture and type (including crevices, fissures and ridges); emergence regime, wind and wave exposure and hence the extent of spray and salt particles up the shore or inland; aspect and hence duration and intensity of light and temperature change; salinity; nutrient levels, and wind, slope, drainage and hence humidity (see sensitivity) (Fletcher, 1973a&b, 1980). For example:

- The lichen flora may be depauperate on hard nutrient poor rocks but more species rich on rough rock surfaces. The lichen flora of calcareous rocks differs from that of siliceous rocks markedly, and the xeric and terrestrial zones may merge, probably due to the difference in water retention of porous calcareous rock and its different chemistry and nutrient levels.
- Rock fissures may support particular lichen communities of shade or drought loving species.
- Wind and wave action affect the deposition of wave splash, sea spray and hence humidity of the shore. Wind driven sea spray may affect inland areas. The lower supralittoral tends to be base-rich and saline while the top of the supralittoral receives acidic, humic, nutrient rich, freshwater runoff from the terrestrial zone. The middle of the supralittoral (the xeric-supralittoral) tends to be the driest.
- The vertical extent of the supralittoral increases with increasing wave and wind exposure and terrestrial species are pushed further up-shore. On wave and wind sheltered shores (low amounts of spray) the mesic-supralittoral communities may be poor, and have less rocky surface to colonize due to penetration of terrestrial plants down the shore.
- Increased wind exposure alone causes increased desiccation and physical abrasion, reducing the numbers of species present.
- On shaded shores the supralittoral lichen zones are narrower but species coverage and richness is increased, partly because the environment is less harsh and partly due to greater development of terrestrial flora.

Faunal complexity

Supralittoral lichens trap detritus and provide a habitat, refuges and food for a number of species of Protozoa, Nematoda, Rotifera, Oligochaeta, Tardigrada, Insecta, Acari, and Mollusca, and a hunting ground for Acari, Arachnida, Insecta and birds (Gerson & Seaward, 1977; Fletcher, 1980; Pugh & king, 1985a&b, 1988; Morgan & Lampard, 1986; Kinchin, 1994):

- Pugh & King (1988) noted that the acarid mite fauna was divided into: maritime species generally confined to the supralittoral; non-maritime mites of terrestrial origin that forage or seek refuge in the supralittoral, and nomadic species that migrate freely between the littoral and supralittoral. The diversity of acarid mites was correlated with lichen growth form. Low encrusting lichens (e.g. *Ochrolechia parella* and *Tephromela atra var. atra*) supported few acarids. More foliose or cracked lichens (e.g. *Caloplaca marina* and *Xanthoria parietina* form pockets of detritus and support numerous acarids, while the bushy, erect growth of *Ramalina siliquosa* trapped little detritus and hence harboured few acarids. The zonation of different species of acarid is also dependant on shore height, desiccation, temperature and inundation (for details see Pugh & King, 1985b, 1988).
- Different species of tardigrades (water-bears) were found to be associated with different lichens and/or different shore heights in the supralittoral and littoral zones (Morgan & Lampard, 1986; Kinchin, 1994).
- The underside of lichens and rock crevices provide refuge for other arthropods such as the bristletail *Petrobius maritimus* and spring-tails (Collumbola) (Joosse, 1976; Gerson & Seaward, 1977).
- Damp rock crevices provide refuges for the sea slater *Ligia oceanica* and the gastropod *Melarhaphe neritoides* in the lower supralittoral and littoral fringe.

Productivity

Little information concerning the energetics and productivity of lichen communities was available (Gerson & Seaward, 1977). Terrestrial lichen communities support large numbers of invertebrates, the lichens provide primary production to lichenophagous species and trap or generate detritus for detrivores, which are in turn consumed by predators (see ecological relationships). The annual primary productivity of lichen heaths was estimated to be only 100g/m^2 (Gerson & Seaward, 1977) but supralittoral communities are probably less productive. Fletcher (1980) suggested that lichens had low food value and low biomass so that few organisms were able to digest them and that supralittoral were, therefore, of more importance due to the cover and niches they provided rather than their productivity.

Recruitment processes

Colonization by lichens on the rocky shore has not been studied (Fletcher, 1980). Fletcher (1980) suggested that the fungal ascospores germinate on suitable substrata to form a 'plaque' and then trap the required species and physiological strain of microalgae to form the symbiotic lichen. Most thalli probably develop from the germination of several ascospores. The required symbiotic microalgae are probably free-living and ubiquitous, e.g. *Hyella caespitosa* is the symbiotic alga in the lichen *Arthopyrenia*, *Calothrix scopulorum* is the symbiotic alga of *Lichina*, and *Trebouxia arborcoa* is the symbiotic alga of *Xanthoria parietina* (Fletcher, 1980; Meier *et al.*, 2002). Fletcher (1980) suggested that the substratum surface probably requires modification by weathering before lichens can establish, so that colonization and initiation of new thallus growth were thought to take several years after exposure of new substratum.

Lichen ascospores and asexual propagules (isidia, blastidia, or soredia) may be transported by the wind and water. Ascospores may be transported in the guts of rotifers or grazing molluscs that may not fully digest spores, which could potentially germinate in their faeces (Honegger, 1997; cited in Meier *et al.*, 2002). Similarly, asexual propagules may be dispersed attached to mobile insect fauna (Gerson & Seaward, 1977). In addition, fragmentation of the thallus can provide another dispersal mechanism, whereby fragments fall or are transported by wind and water to colonize other suitable substrata (Honegger, 1997; cited in Meier *et al.*, 2002). For example, *Xanthoria parietina* does not produce symbiotic vegetative propagules and its symbiotic algae (the photobiont) *Trebouxia spp.* are rare outside lichen thalli. However, Meier *et al.* (2002) demonstrated that the faeces of the lichenivorous mites *Trhypochtonius tectorum* and *Trichoribates trimaculatus* contained viable fungal ascopsores and algal cells, and suggested that mites faeces was a possible mode of short and long range dispersal of *Xanthoria parietina* and other lichens. In addition, fragments of the thallus of *Xanthoria parietina* transplanted to suitable substrata will attach and grow (Armstrong, 1994; Honeggar, 1996). In the field, the thallus fragments naturally. Honeggar (1996) reported that fragments of its thallus that fell onto suitable substratum (a concrete cupola visited an by seabirds, and hence nutrient enriched) could attach in 6-9 months and give rise to new growth unless they landed upside down. Honeggar (1996) noted that shelter from strong winds was required to allow the fragments to attach. In experiments, finely fragmented thallus primordial stages of new lobes appeared within ca one year (Honeggar, 1996).

Tardigrades and other microscopic fauna (e.g. rotifers and nematodes) are probably incapable of significant active dispersal. Tardigrades, rotifers and nematodes may be dispersed in water droplets or attached to more mobile species such as insects. In dry conditions, tardigrades are capable of dehydrating (anhydrobiosis) to form dormant 'tuns', which could potentially be dispersed by wind (Kinchin, 1994). Tardigrades reproduce either sexually or asexually depending on species and asexual species are often associated with rapid colonization of habitats (Kinchin, 1994). The remaining fauna (e.g. acarid mites, and insects) are highly mobile and probably capable of rapid colonization of available habitats from either the surrounding littoral, supralittoral or terrestrial habitats.

Time for community to reach maturity

The asexual propagules and sexual ascospores of lichens, and their symbiotic microalgae are probably ubiquitous (except *Xanthoria parietina*, see above), so that colonization of suitable habitats would be relatively rapid once the substrata were suitably modified by weathering (see above). Lichens are very slow growing, rarely exceeding 2-5 mm/ year (Jones *et al.*, 1974). For example: crustose lichens were reported to show radial increases of 0.1 mm/month while foliose species grow at 0.4-0.7 mm/month (Fletcher, 1980); *Lichina pygmaea* was reported to grow 3-6 cm/year at one site but only 0.5 mm/year at others (Fletcher, 1980), and *Ramalina siliquosa* grew at 2-3 mm/year and *Parmelia sulcata* at 8 mm/year while most crustose species grew between 0.5-1 mm/year in Sullom Voe (James & Syratt, 1986). However, lichen growth rates varied widely between different locations, between different species and even between different thalli of the same species at the same site (Fletcher, 1980; Sancho *et al.*, 2007). Cullinane *et al.* (1975) noted that many of the lichens lost due to an oil spill in Bantry Bay were probably 20-50 years old, based on their size, and lifespans of lichens have been estimated to be 100 years or more (Jones *et al.*, 1974) and possibly up to 7000 years in the Antarctic (Sancho *et al.*, 2007). However, lichen growth rates vary widely and many but not all lichens of extreme climates have slow growth rates. The highest growth rates are recorded in moist coastal-influenced regions, and lichens from temperature, tropical or sub-tropical areas may grow between a few millimetres to a few centimetres per year (Honeggar, 2008). Honeggar (2008) suggested that longevity in lichens required critical interpretation.

On rocky shores, succession was not clear, and lichen colonization tended to depend on available suitable substrata, rather than a successional pattern (Fletcher, 1980). In some instances, the dying centres of some lichen thalli may be colonized by other lichen species. Overgrowth of one lichen species by another does not appear to be a regular occurrence on supralittoral or littoral rocky shores (Fletcher, 1980).

Overall, it may take several years for lichens to colonize new substrata and several more years to grow enough to provide shelter or refuges for invertebrate fauna. The invertebrate fauna itself is likely to be able to colonize the available habitat quickly.

Additional information

None

Preferences & Distribution

Habitat preferences

Depth Range	
Water clarity preferences	Not relevant
Limiting Nutrients	Calcium, Nitrogen (nitrates)
Salinity preferences	Full (30-40 psu), Variable (18-40 psu)
Physiographic preferences	Enclosed coast / Embayment, Open coast, Strait / sound
Biological zone preferences	Supralittoral
Substratum/habitat preferences	Bedrock, Large to very large boulders
Tidal strength preferences	Not relevant
Wave exposure preferences	Exposed, Moderately exposed, Sheltered, Very exposed, Very sheltered
Other preferences	Hard siliceous rocks

Additional Information

Geographical distribution
The west shores of Britain and Ireland exhibit more species rich lichen communities than eastern shores. Foliose-terrestrial or sun-loving species are conspicuously absent from eastern shores (Fletcher, 1980). The xeric-supralittoral zone is better represented in south west England and Ireland than in western Scotland, presumably because the lower temperatures and increased rainfall of western Scotland increase leaching from terrestrial habitats and reduced saline influence. The lack of terrestrial (rather than maritime) lichens in south west Britain is probably due to an excess of seawater spray.

Habitat preferences
Each species of lichen inhabits a very narrow range of environmental conditions and are particularly susceptible to environmental change (Jones *et al*., 1975). The supralittoral lichen zone probably exhibits its greatest vertical extent on wave and wind exposed shores, although the species richness and cover is probably greatest on sheltered shores. The vertical distribution of supralittoral species is dependent on a number of environmental factors (see 'zonation' under 'habitat complexity', Fletcher, 1980), however, the primary factors appear to be water availability and desiccation, wind abrasion, salt and nutrients, light intensity and the availability of suitable substrata (for details see individual sensitivity assessments and Fletcher, 1980).

This biotope is characteristic of hard siliceous rock substrata. In the supralittoral, the rock chemistry and texture affects the lichen flora so that the lichens become separated by their salinity and nutritional tolerances. Supralittoral quartzites are almost pure silica and bear depaurate lichen floras dominated by *Ramalina siliquosa*, while sandstones bear species characteristic of soft siliceous rocks (Fletcher, 1980). Calcareous rocks support few exclusively maritime lichen species. Fletcher (1980) suggested that the ready supply of calcium on calcareous substrata satisfied the lichen's nutritional requirements so that the distribution of lichens was affected primarily by salinity. Soft rocks bear specialized lichen communities and the reader should refer to Fletcher (1980) for details or to LR.Chr for the sensitivity of a similar supralittoral soft chalk biotope.

Species composition

Species found especially in this biotope

- *Armeria maritima*
- *Caloplaca marina*
- *Ligia oceanica*
- *Ochrolechia parella*
- *Ramalina siliquosa*
- *Tephromela atra*
- *Verrucaria maura*
- *Xanthoria parietina*

Rare or scarce species associated with this biotope

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Additional information

Fletcher (1980) reported that almost 450 species of lichen occurred on mid-littoral and supralittoral rocky shores around Britain and represented about one third of the British lichen flora. Fewer species are likely to occur on a single shore, for example Fletcher (1980) suggested that a shore in Wales would typically support 150 lichen species while a Northumberland shore may only support 40-60 species. Pugh & King (1988) reported 77 species of acarid mites from the supralittoral, the majority from lichens and tidal debris, although the diversity of species varies with location. Morgan & Lampard (1986) reported 7 species of tardigrade from only 4 species of supralittoral lichen on the Great Cumbrae. The lichen flora probably also supports a variety of spring tails (Collumbola), maritime insects, pseudoscorpions and spiders that are not generally recorded in surveys, so that species richness is likely to be underestimated.

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The yellow and grey lichens biotope (LR.FLR.Lic.YG) describes a range of lichen communities in several zones in the supralittoral, separated by the aspect, height and slope of the shore, the amount of spray and shading, the type of rock surface, crevices, and runoff. The habitat is dominated by either yellow and orange lichens (e.g. *Caloplaca* spp. and *Xanthoria parietina*) or the grey lichens (e.g. *Ramalina siliquosa*, *Tephromela atra* var. *atra*, *Rhizocarpon constrictum*, *Parmelia prolixa*, *Anaptychia runicata* (as *fusca*), *Lecanora* sp. and *Ochrolechia parella*) Supralittoral lichens provide primary productivity, trap detritus and provide a habitat, refuges and food for a number of species of Protozoa, Nematoda, Rotifera, Oligochaeta, Tardigrada, Insecta, Acari, and Mollusca, and a hunting ground for Acari, Arachnida, Insecta and birds (see habitat complexity above).

A few species of acarid mites and tardigrades are closely associated with and possibly dependent on a few species of supralittoral lichen. In addition, the mites may also assist in the dispersal and recruitment of some lichens species (see recruitment processes above). However, most of the microfauna are probably highly mobile and widespread on the shore.

Therefore, the sensitivity of the biotope is based on the sensitivity of the lichen community. The sensitivity assessment addresses all the separate lichen communities but any differences in their response to disturbance are highlighted where possible.

Resilience and recovery rates of habitat

Sexual spores and asexual propagules of lichens are probably widely dispersed by the wind and mobile invertebrates while the microalgal symbionts are probably ubiquitous (except *Xanthoria parietina*). The thallus of lichens often dies from the centre out, growth occurring at the margin edge. However, fragments of the remaining thallus continue to grow, often faster than in a large thallus. Nevertheless, lichen growth rates are low, rarely more than 0.5-1 mm/year in crustose species while foliose species may grow up to 2-5 mm/year (see 'time to reach maturity' above). For example: crustose lichens were reported to show radial increases of 0.1 mm/month while foliose species grow at 0.4-0.7 mm/month (Fletcher, 1980); *Lichina pygmaea* was reported to grow 3-6 cm/year at one site but only 0.5 mm/year at others (Fletcher, 1980), and *Ramalina siliquosa* grew at 2-3 mm/year and *Parmelia sulcata* at 8 mm/year while most crustose species grew between 0.5-1 mm/year in Sullom Voe (James & Syratt, 1986). However, lichen growth rates varied widely between different locations, between different species and even between different thalli of the same species at the same site (Fletcher, 1980; Sancho *et al.*, 2007). Cullinane *et al.* (1975) noted that many of the lichens lost due to an oil spill in Bantry Bay were probably 20-50 years old, based on their size, and lifespans of lichens have been estimated to be 100 years or more (Jones *et al.*, 1974) and possibly up to 7000 years in the Antarctic (Sancho *et al.*, 2007). However, lichen growth rates vary widely and many but not all lichens of extreme climates have slow growth rates. The highest growth rates are recorded in moist coastal-influenced regions, and lichens from temperature, tropical or sub-tropical areas may grow between a few millimetres to a few centimetres per year (Honeggar, 2008). Honeggar (2008) suggested that longevity in lichens required critical interpretation.

Fletcher (1980) suggested that newly exposed substratum needs to be modified by weathering and that initiation of the new thallus is thought to take several years. Crump & Moore (1997) observed that lichens had not colonized experimentally cleared substrata within 12 months.

Brown (1974) reported that recolonization of substrata within Caerthillian Cove, Cornwall, which was heavily affected by oil and dispersants after the *Torrey Canyon* oil spill, took 7 years to begin. Moore (2006) reported that the recovery of supralittoral lichen cover after the *Sea Empress* oil spill was faster in sunny sites than in shaded sites but varied with location, based on observations of quadrats ten years after the spill in west Angle Bay and Hopgang, south Wales. Moore (2006) reported that *Caloplaca* sp. grew quickly and showed signs of recovery soon after the oil had been removed while *Xanthoria parietina* could grow at 1 cm/year but *Ochroleuca parella* growth was slow at ca 1mm/year. On sunny south facing supralittoral rocks in West Angle Bay were 'covered in lichens' within five years but shaded north facing areas had large areas of bare rock ten years after the spill, although *Caloplaca* colonies grew back quickly (Moore, 2006). However, at Sawdern Point, *Caloplaca* colonization and growth was faster on areas that were left alone than areas subject to high pressure washing (Moore, 2006). At Hopgang, recovery of *Ochroleucia parella* was slow (Moore, 2006).

Resilience assessment. Mobile invertebrate fauna will probably recolonize rapidly, however, recovery of lichens communities from damage will probably take many years. Where members of the community experience some damage (**Medium** resistance), regrowth is likely, and fragmentation may result in the colonization of more space (e.g. *Xanthoria parietina*), but recovery is likely to take between 2 and 10 years depending on location. Therefore, resilience would be assessed as '**Medium**'. In heavily damaged areas, where a significant proportion of the population (abundance or cover) is damaged or removed (resistance is 'Low' or 'None') the orange and yellow lichens may recover within 2-10 years depending on location (**Medium** resilience) but areas dominated by grey lichens are likely to be slow, probably in excess of ten years (Holt *et al*., 1995). Therefore, the resilience of the biotope would be assessed as '**Low**'.

Hydrological Pressures

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

Supralittoral lichens are exposed to extremes of temperature from hot, dry summers to cold, frosty winters. Fletcher (1980) noted that few studies implicated high or low temperatures as a factor affecting seashore lichens, but that changes in temperature affect water relations. Increased temperature may increase desiccation (see emergence) although, other factors are involved, such as wind and wave action (splash and spray), precipitation, dew, sunlight and shading. The characterizing lichen species are widely distributed around Britain and Ireland and unlikely to be adversely affected by changes in temperature at the benchmark level. Therefore, a resistance of **High** is suggested. Resilience is, therefore, likely to be **High**, and the biotope has been assessed as **Not sensitive** at the benchmark level. Ellis *et al.* (2007) modelled the effect of climate change scenarios on selected terrestrial lichens and identified potential threats to Northern montane and Boreal species, and uncertainties in the fate of species typical of the Atlantic coast margin, but no information on supralittoral species was found.

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

Supralittoral lichens are exposed to extremes of temperature from hot, dry summers to cold, frosty winters. The characterizing lichen species are widely distributed around Britain and Ireland and unlikely to be adversely affected by changes in temperature at the benchmark level. However, a decrease in temperature is likely to decrease the risk of desiccation (see above) and increase the average humidity of the shore. Fletcher (1980) suggested that the lower average temperatures and increased rainfall of the shores of western Scotland resulted in a reduced xeric-supralittoral zone (the *Ramalina siliquosa* belt). Overall, the biotope will remain, and although the relative extent of the supralittoral lichen zones and species composition is likely to change in the long-term. Therefore, a resistance of **High** is suggested. Resilience is, therefore, likely to be **High**, and the biotope has been assessed as '**Not sensitive**' at the benchmark level.

Salinity increase (local)	High Q: High A: Low C: Medium	High Q: High A: Medium C: Medium	Not sensitive Q: High A: Low C: Medium

The mesic-supralittoral is the only supralittoral zone subject to direct inundation by seawater. The supralittoral is exposed to a harsh regime of fluctuating salt (ionic) concentration due to deposition of wave splash or sea spray, subsequent evaporation and increased concentration, and the freshwater influences of rain, dew and runoff. Fluctuations in salt concentration and saline influence are important determinants of supralittoral zonation (Fletcher, 1980) Therefore, an increase in saline influence, e.g. via increased sea spray deposition is likely to have similar effects to that of increased wave exposure; an increase in the height of supralittoral zones, especially the xeric, on the shore, as the terrestrial lichens are pushed further inland. Supralittoral lichen zones are likely to increase in extent, although it may take more than a year (see benchmark) for the effects to be observable and, therefore, a resistance of '**High**' is recorded. As resilience is '**High**' (by default), the biotope is assessed as '**Not sensitive**'. (Please note the benchmark is not directly applicable to the supralittoral).

Salinity decrease (local)	High Q: High A: Low C: Medium	High Q: High A: Medium C: Medium	Not sensitive Q: High A: Low C: Medium

A decrease in the extent of the biotope in estuaries is probably more related to the reduction of wave action and sea spray, and the lack of suitable substrata than a reduction in salinity itself. Increased freshwater runoff or rainfall is likely to allow halophilic terrestrial lichens and vegetation to colonize further down the shore, forming lichen communities similar to those of shaded shores. For example, Fletcher (1980) reported that the xeric-supralittoral zone was better represented in south west Britain and Ireland than western Scotland, where even wind exposed shores bear halophobic terrestrial species. Fletcher (1980) suggested that the increased rainfall and lower temperatures in western Scotland mitigated the effect of salinity and sea spray.

A reduction in saline influence is likely to allow more terrestrial species to colonize further down the shore, increasing species richness but reducing the extent of the biotope. The availability of water, salinity and pH are important factors in the zonation of supralittoral lichen communities, so that the biotope probably has a **Medium** sensitivity (a **Medium** resistance and resilience) to changes in salinity. However, it may take more than a year (see benchmark) for the effects to be observable and, therefore, a resistance of '**High**' is recorded. As resilience is '**High**' (by default), the biotope is assessed as '**Not sensitive**'. (Please note the benchmark is not directly applicable to the supralittoral).

Water flow (tidal current) changes (local)	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 supralittoral is unlikely to be affected by changes in water flow as described in the pressure benchmark. Runoff due to heavy rainfall is possible but is outside the scope of the pressure. Therefore, the pressure is **Not relevant**.

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

The emergence regime, that is the time covered or uncovered by the tide, is likely to change the amount of wave or wind driven spray and splash deposited on the supralittoral zone and, hence, the frequency of drying and wetting of lichens, especially on sheltered shores, The levels of moisture and relative duration of wet and dry periods are the most important factors controlling vertical zonation in supralittoral lichens. Water is supplied by tidal inundation, wave splash or sea spray at the bottom of the shore but by rainfall and runoff at the top of the shore. Rates of evaporation and hence desiccation is dependent of the slope and drainage of the shore, the rock type and its porosity, temperature and hence insolation and aspect, and wind exposure. Any activity that changes the exposure of the shore to wind, wave, rain or sunlight is likely to affect supralittoral communities.

- The xeric-supralittoral receives the least amount of water from sea or land together with the greatest degree of evaporation and is, therefore, the driest and most drought-prone zone (Fletcher, 1980).
- The number of lichen species decreases on wind exposed shores, due to the loss of foliose species (e.g. *Parmelia* sp.), xeric-supralittoral and terrestrial lichens, and total lichen cover is reduced.
- Supralittoral lichens take up water faster than it is lost, unlike their littoral counterparts (Fletcher, 1980).
- Growth form and thallus structure affects desiccation rates with crustose and closely appressed forms having lower rates of water loss (Fletcher, 1980).
- Supralittoral lichens were reported to respire at 5-20% water saturation and photosynthesize at 10-30% although littoral species required 30-50% to respire and greater than 40% water saturation to photosynthesize (for further details see Fletcher, 1980).
- Exposure to 21 hr drought and 3 hr submersion for 14 days in supralittoral lichens broke down their symbiosis resulting in liberation of the microalgal symbiont. Fletcher (1980) concluded that the lichen symbiosis required a suitable balance of dry and wet periods for each species.

Although supralittoral lichens are probably highly tolerant of high levels of desiccation when compared to littoral species, each species probably lives within a narrow range of environmental conditions and are intolerant of changes in the moisture levels and desiccation (Jones *et al.*, 1974; Holt *et al.*, 1995).

An increase in emergence will reduce the inundation of the mesic and submesic supralittoral and littoral fringe, and reduce the upper extent of sea spray, especially on sheltered shores. Johannesson (1989) attributed the zone of bare rock (devoid of marine and terrestrial life) found on non-tidal rocky shores in Sweden, to prolonged periods of submergence and emergence due to changes in tidal height by atmospheric pressure. An increase in emergence could potentially allow the mesic and xeric supralittoral zones to increase in extent down the shore while halophilic terrestrial lichens may colonize the upper supralittoral. However, in one year (see benchmark) little difference is likely to be observed since lichens grow and colonize slowly, and the effects only manifest themselves if the change in emergence is prolonged.

A decrease in emergence will increase the inundation of the lower supralittoral (mesic and submesic zones) and may increase the effects of wave splash further up the shore. In a one year period (see benchmark) the mesic and submesic species are likely to be reduced in extent while the littoral fringe communities are likely to increase in extent. If the decrease in emergence is prolonged the upper limit of the mesic and submesic zones is likely to increase while the extent of the xeric will decrease.

The classification of acarid mites into maritime, nomadic or terrestrial species is partly related to their response to inundation by seawater (Pugh & King, 1985b). The zonation of different species of acarid mites is partly determined by their tolerance to desiccation (Pugh & King, 1985b) so that the acarid species composition will probably change, with an increase in the number of terrestrial species.

Sensitivity assessment. Overall, the extent of the biotope in the lower supralittoral and its species richness is likely to decrease due to a decrease in emergence (increased inundation) and loss of the lower supralittoral so that the biotope probably has a **Medium** sensitivity (a **Medium** resistance and resilience) to changes in salinity.

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

The biotope has been recorded from very wave exposed to wave sheltered environments. Increased wave exposure raises the height of the lichen zones, reduces the number of species present and the overall lichen cover, and reduces the lower limit of terrestrial vegetation (Fletcher, 1973b,1980) due to an increase in the amount of wave splash and sea spray. As a result, the mesic and xeric zones increase in vertical extent. Increased wave action may remove some species, e.g. *Xanthoria parietina* which becomes restricted to fissures and crevices on wave exposed shores. On very wave exposed shores, littoral fringe and mesic-supralittoral lichen species may extend into the terrestrial zone. Overall, an increase in wave exposure is likely to increase the extent of the biotope, although species richness will decline. The extent of the area affected by sea spray (seawater droplets and salt) is also affected by wind exposure (see additional information below). It should be noted that the effects will probably take more than a year to become observable.

Lichen cover increases on shores sheltered from wave or wind generated sea spray but the vertical extent of the supralittoral zones are much reduced in extent due to downward penetration of terrestrial vegetation. The mesic-supralittoral is poorly represented on sheltered shores (Fletcher, 1973b, 1980). Therefore, a decrease in wave exposure is likely to reduce the extent of the supralittoral lichens zone, although the abundance of individual species present may increase, and a recognisable biotope remain.

Sensitivity assessment. Therefore, the supralittoral lichen communities are likely to exhibit a **Medium** resistance to changes wave exposure, with a **Medium** resilience and hence **Medium** sensitivity. However, a 3-5% change in significant wave height (the benchmark) is unlikely to be significant except in the most sheltered examples of the biotope, where even a minor increase in wave action may allow the supralittoral lichens to increase in extent. Therefore, a resistance of **High** is recorded. Hence, resilience is **High** and the biotope is **Not sensitive**.

Chemical Pressures

	Resistance	Resilience	Sensitivity
Transition elements & organo-metal contamination	High Q: High A: Medium C: Medium	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: Medium

Lichens are known indicators of heavy metals in the environment, especially iron (Seaward, 2008). Seashore lichens often indicate environmental concentrations of heavy metals or accumulate them, frequently to very high levels (Fletcher, 1980). The accumulation of high levels of heavy metals may deter grazers (Gerson & Seaward, 1977). For example, *Verrucaria maura* was reported to accumulate Fe to 2.5 million times over the concentration in seawater, and Zn by a factor of 8000. Some species accumulate lead to 100 ppm and cadmium to 2 ppm of thallus dry weight (Fletcher, 1980). Heavy metals may be derived from rainfall, and dust as well as seawater (Fletcher, 1980). Gerson & Seaward (1977) noted that accumulated heavy metals could potentially accumulate up lichen based food webs, e.g. the lichen to caribou to man food chain in Alaska. However, no information on bioaccumulation through supralittoral communities was found. Overall, the ability of lichens to accumulate heavy metals to such high levels suggests a 'High' resistance to the heavy metal ions studied. Therefore, the lichen community is probably **'Not sensitive** to heavy metal contamination.

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

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

Several studies have documented the effects of oil spills on supralittoral lichen communities, although in many cases is difficult to separate the effects of oiling from the effects of dispersants.

- Ranwell (1968) reported 19 species of lichens that were killed by oil or dispersants, including the characterizing species *Lichina* sp., *Caloplaca marina*, *Caloplaca thallincola*, *Tephromela atra*, *Ochrolechia parella*, *Ramalina siliquosa*, and *Xanthoria parietina*.
- Smith (1968) reported that *Xanthoria parietina* grew even under a covering of weathered oil while Crump & Moore (1997) noted that *Caloplaca marina* survived 10 months under weathered oil.
- Oil inundation caused discoloration of the thallus (e.g. *Xanthoria parietina* became dark brown), especially of the fruiting bodies, or bleaching of the thallus, while brittle tough thalli of *Ramalina siliquosa* and *Lichina pygmaea* became flaccid, soft and slimy (Cullinane *et al.*, 1975).
- In Bantry Bay, Cullinane *et al.* (1975) reported that a spill of crude oil affected fructicose species most of all, crustose species the least while foliose species were affected at an intermediary level. Gelatinous and crustose lichens absorbed the oil and were removed from the substratum. *Xanthoria parietina* was the most severely affected species, while *Ramalina siliquosa*, *Lichina pygmaea* and *Dermatocarpon miniatum* were obviously affected (Cullinane *et al.*, 1975). Cullinane *et al.* (1975) listed nine species of lichen damaged by oil.
- Crump & Moore (1997) reported that oiling with crude oil followed by fuel oil from the *Sea Empress* spill, severely damaged *Ramalina siliquosa* and *Xanthoria parietina*, resulting in necrosis, bleaching and peeling from the substratum. Almost all the *Xanthoria parietina* surviving after the spill in September 1996 had died by February 1997. *Caloplaca thallincola* was also damaged.

- Moore (2006) reported that the recovery of supralittoral lichen cover after the *Sea Empress* oil spill was faster in sunny sites than in shaded sites but varied with location, based on observations of quadrats ten years after the spill in west Angle Bay and Hopgang, south Wales. Moore (2006) reported that *Caloplaca* sp. grew quickly and showed signs of recovery soon after the oil had been removed while *Xanthoria parietina* could grow at 1 cm/year but *Ochroleuca parella* growth was slow at ca 1mm/year.
- On sunny south facing supralittoral rocks in West Angle Bay were 'covered in lichens' within five years but shaded north facing areas had large areas of bare rock ten years after the spill, although *Caloplaca* colonies grew back quickly (Moore, 2006). However, at Sawdern Point, *Caloplaca* colonization and growth was faster on areas that were left alone than areas subject to high pressure washing (Moore, 2006).
- At Hopgang, recovery of *Ochroleucia parella* was slow (Moore, 2006).

Several of the characterizing species are probably highly sensitive of oiling while others demonstrate sublethal effects and are likely to be damaged by oiling, depending on the type and weathering of the oil. Oiling is likely to have adverse effects of the invertebrate fauna, either through toxicity or smothering and especially through loss of the lichen habitat.

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.

Dispersants and detergents. Several studies have documented the effects of oil spills on supralittoral lichen communities, although in many cases is difficult to separate the effects of oiling from the effects of dispersants. Most studies concluded that the decontamination methods, (including dispersants) were more toxic to lichens than the oil itself.

- Ranwell (1968) reported 19 species of lichens that were killed by oil or dispersants, including the characterizing species *Lichina* sp., *Caloplaca marina*, *Caloplaca thallincola*, *Tephromela atra*, *Ochrolechia parella*, *Ramalina siliquosa*, and *Xanthoria parietina*.
- In Bantry Bay, walls washed with the detergent (dispersant) BP1100X were very clean. Although crustose species were little affected, *Caloplaca citrina* had turned green, *Physcia* sp. and other foliose species were absent and *Xanthoria parietina* thalli had changed colour and were peeling off (Cullinane *et al.*, 1975).
- Laboratory treatment (24hr) of lichens with dispersants resulted in discoloration, loss of chlorophyll and algal cells in several species (Brown, 1974).
- Heavy use of dispersants in Caerthillian Cove, after the *Torrey Canyon* oil spill, was reported to have 'annihilated' the lichen flora, and subsequent recolonization did not begin until 7 years later (Brown, 1974).
- Lichen communities were also reported to be affected by trampling during clean up and to be highly intolerant of high pressure spray washing techniques (see abrasion above) (Ranwell, 1968; Cullinane *et al.*, 1975; Crump & Moore, 1997; Menot *et al.*, 1998).

Air pollution. The effects of air pollutants on terrestrial lichens and their use as indicator species have been studied extensively (Holt *et al.*, 1995) although few studies refer to maritime species (see reviews and bibliographies by Henderson (1999), Richardson (1992), NHM (2002), Nash, 2008). Fletcher (1980) suggested that supralittoral lichens were less resistant of air pollution than littoral species, and had disappeared in the Clyde estuary and north eastern England. Studies of terrestrial locations suggest that *Xanthoria parietina* was more resistant of air pollution than other lichens, although germination and growth were inhibited (Holt *et al*., 1995; Dobson, 2000). Jones *et al*. (1974) attributed dying *Ramalina siliquosa*, *Verrucaria maura*, *Caloplaca marina* and *Lichina pygmaea*, and a reduced cover of *Xanthoria parietina* in Bull Bay, Anglesey to fumes from a nearby petroleum plant, which were also reported to make working on the shore unpleasant.

Overall, lichen species sensitivities vary, many of the characterizing species are intolerant of atmospheric pollution and synthetic chemicals.

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

Lichens have also been reported to accumulate radionuclides in a similar manner to other heavy metals (see above) (Gerson & Seaward, 1977; Fletcher, 1980). Radionuclides could potentially accumulate up food webs based on lichen species, however, no further evidence was found.

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	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 supralittoral is rarely inundated and is, therefore, permanently exposed to the air. The biotope is unlikely to be exposed to deoxygenated conditions.

Nutrient enrichment	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not sensitive Q: NR A: NR C: NR

Nutrient levels are a determining factor in supralittoral lichen zonation. Nutrient-rich, acid runoff from terrestrial habitats influences the top of the supralittoral while saline, basic conditions dominate at the bottom of the shore. Heavy bird manuring can result in loss of the xeric-supralittoral to submesic lichen species such as *Xanthoria parietina*, *Xanthoria candelaria* and *Caloplaca verruculifera* (Fletcher, 1980). However, *Xanthoria parietina* is considered to be a nitrophilous species (Fletcher, 1980; Wootton, 1991; Armstrong, 1994; Honeggar, 1996). Wootton (1991) reported that the presence of guano on the shores of Washington State resulted in the loss of grey lichens allowing the orange lichens (*Caloplaca marina* and *Xanthoria elegans*) to colonize further up the shore (Wootton, 1991; Holt *et al*., 1995). The lichen *Aspicilia leprosescens* is exclusively associated with bird perches on siliceous rocks (Fletcher, 1980). Large populations of the lichen *Candelariella vitellina* on the shore are indicative of nutrient enrichment (Fletcher, 1980; Holt *et al*., 1995). Siliceous rocks are nutrient poor and dominated by grey lichens e.g. *Ramalina siliquosa*. It is likely that an increase in nutrients may promote lichen communities of more nutrient rich calcareous rocks or halophilic terrestrial lichen species.

Sensitivity assessment. Nutrient enrichment by bird manuring is likely to result in an increase in 'orange belt' submesic species but the biotope will still be identifiable. An increase in nutrient runoff from the terrestrial zone, e.g. due to agricultural fertilizer and sprays may allow the halophilic terrestrial lichens species or species typical of calcareous rocks to colonize further down the shore, reducing the extent of the supralittoral lichen zone. Therefore, the biotope may exhibit a **Medium** resistance to nutrient enrichment, albeit at low confidence. However, this biotope is considered to be **'Not sensitive'** at the pressure benchmark that assumes compliance with good status as defined by the WFD.

Organic enrichment	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

Little evidence of the effects of organic enrichment was found. Wotton (1991) demonstrated an increase in the extent of orange lichens, and loss of grey lichens due to guano from seabirds (see nutrient enrichment), although guano is a rich source of nitrogen and phosphorus rather than organic materials. Similarly, Favero-Longo *et al.* (2011) described the major changes in coastal lichens (mainly terrestrial species) due to excretion by fur seals in the South Orkney Islands attributed to elevated levels of nitrogen. Fletcher (1980) noted that the organic content of water increases further up the shore in the xeric zone, due to runoff from terrestrial habitats.

Sensitivity assessment. No evidence on the effects of organic enrichment on supralittoral lichen communities was found and no assessment was made.

Physical Pressures

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

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

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

The supralittoral lichen communities typical of this biotope are only found on hard substrata and dominate rocks in the supralittoral. A change to a sedimentary substratum, however unlikely, would result in the permanent loss of the biotope. Therefore, the biotope has a resistance of **None**, with a **Very low** resilience (as the effect is permanent) and, therefore, a sensitivity of **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 sediment type)	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not Relevant on hard rock biotopes.

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

Not Relevant on hard rock biotopes.

Abrasion/disturbance of the surface of the substratum or seabed	Low Q: High A: Medium C: Medium	Low Q: High A: Medium C: Medium	High Q: High A: Medium C: Medium

The biotope is susceptible to trampling by birds (in heavily populated sites), animals and man, animal rubbing and the physical abrasion caused by the wind.

- Physical abrasion by wind may discourage large foliose and fructicose lichens (Fletcher, 1980).
- Fletcher (1980) noted that large specimens of lichens, e.g. *Ramalina siliquosa*, were only found on vertical rocks inaccessible to animals, including man.
- James & Syratt (1987) noted that rubbing by animals (e.g. sheep) damaged lichens resulting in loss of parts of some thalli and loss of *Ramalina siliquosa* at some sites while it showed signs of regeneration at some sites.
- Trampling damage is greatest when the thallus is wet, causing it too peel from the surface, while when dry, some fragments are likely to remain to propagate the lichen (Fletcher, 1980).
- Physical disturbance of the lichen flora or substratum may reduce species richness and favour more rapid growing, disturbance tolerant species, e.g. *Lecanora dispersa*, *Candelariella vitellina* and *Rinodina gennerii* (Fletcher, 1980)
- Extreme physical abrasion due to high pressure water cleaning techniques (used to clear oil after spills), damaged lichens even at low pressures, especially *Ramalina siliquosa*, *Xanthoria* sp. and *Caloplaca marina*, and removed all supralittoral lichens at high pressures (Crump & Moore, 1997; Menot *et al.*, 1998).

Sensitivity assessment. Animal trampling and rubbing are likely to remove a proportion of lichen thalli in the short-term, and alter the lichen communities in the long-term. Therefore, a resistance of **Low** has been recorded. Resilience is likely to be **Low** so that sensitivity is probably **High**.

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

Penetration is unlikely to be relevant to hard rock substrata. Therefore, the pressure is **Not relevant.**

Changes in suspended solids (water clarity)	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 supralittoral is rarely covered in water, except at its lowest extent on the shore and extreme high tides. It is unlikely to be exposed to changes in water clarity due to changes in suspended sediment. Therefore, the pressure is **'Not relevant'**.

Smothering and siltation rate changes (light)	High Q: High A: Low C: Medium	High Q: High A: High C: High	Not sensitive Q: High A: Low C: Medium

Fletcher (1980) noted that littoral lichens were eliminated by silt deposition. But most supralittoral species are unlikely to be smothered by sediment. Smothering by wind-blown sediment and dust may occur on sloping surfaces. Smith (1968) noted that *Xanthoria* sp. survived when smothered by weathered oil in the splash zone, and Crump & Moore (1997) noted that *Verrucaria maura* and *Caloplaca marina* survived for 10 months under weathered oil. No information on the effects of smothering on the invertebrate fauna was found, although smothering by oil is probably detrimental. Overall, smothering will probably reduce photosynthesis and growth rates of lichens. Therefore, the biotope would probably survive and a resistance of **High** has been recorded. Hence, resilience is **High** and the biotope is probably **Not sensitive** at the benchmark level.

Smothering and siltation rate changes (heavy)	High Q: High A: Low C: Medium	High Q: High A: High C: High	Not sensitive Q: High A: Low C: Medium

Fletcher (1980) noted that littoral lichens were eliminated by silt deposition. But most supralittoral species are unlikely to be smothered by sediment. Smothering by wind-blown sediment and dust may occur on sloping surfaces. Smith (1968) noted that *Xanthoria* sp. survived when smothered by weathered oil in the splash zone, and Crump & Moore (1997) noted that *Verrucaria maura* and *Caloplaca marina* survived for 10 months under weathered oil. No information on the effects of smothering on the invertebrate fauna was found, although smothering by oil is probably detrimental. Overall, smothering will probably reduce photosynthesis and growth rates of lichens. Therefore, the biotope would probably survive and a resistance of **High** has been recorded. Hence, resilience is **High** and the biotope is probably **Not sensitive** at the benchmark level.

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

Not assessed.

Electromagnetic changes	Not relevant (NR) 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 on the effects of electromagnetic fields was found.

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

No evidence on the effects of noise or vibration was found.

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

Aspect and hence light intensity and duration affect lichen communities primarily by affecting temperature and hence moisture levels. Sunny shores tend to be dominated by orange and white photophilic lichens while shaded shores are dominated by greyer, shade-loving lichen species (see ecology). The supralittoral zones are reduced in height on shaded shores and the xeric-supralittoral is replaced by terrestrial lichens, resulting in an increase in species richness (Fletcher, 1980). However, the extent of the biotope is likely to be markedly reduced by shading. Therefore, a resistance of **Low** is suggested. Resilience is probably **Low** so that the biotope probably has a **High** sensitivity to shading, within the footprint of the activity or structure responsible.

Barrier to species movement	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

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

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

The pressure definition is not directly applicable to the supralittoral so **Not relevant** has been recorded. Collision via ship groundings or terrestrial vehicles is possible but the effects are probably similar to those of abrasion above.

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

Lichens have no visual receptors, so the pressure is **Not relevant**.

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence on the translocation, breeding or species hybridization in lichens was found.

Introduction or spread of invasive non-indigenous species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

Essl & Lambdon (2009) reported that that only 5 species of lichen were thought to be alien in the UK, which is ca 0.3% of the UK's lichen flora. All five species were Parmelia spp. epiphytes, and unlikely to occur in the supralittoral. Essl & Lambdon (2009) note that no threat to competing natives has yet been demonstrated. Although they note that information on the presence or spread of non-indigenous lichens is unclear due to the lack of data on lichen distribution across Europe. Therefore, there is currently not enough evidence on which to base an assessment.

Introduction of microbial pathogens	Not relevant (NR) 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 on disease or pathogens mediated mortality was found.

Removal of target species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

Lichens e.g. *Ochrolechia parella*, have been collected in the past for the manufacture of dyes. The collection of lichens to prepare lichen-dyed tweed has largely stopped (Richardson & Young, 1977), however, no information concerning the use of coastal lichens was found. Extraction of lichens will undoubtedly reduce their abundance but probably not the extent of the supralittoral zone. However, **No evidence** on targetted removal was found.

Removal of non-target species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

No commercial or recreational activities thought to occur in the supralittoral are likely to remove lichens as by-catch or by accident. Recreational activities that traverse the supralittoral (e.g. recreational angling, access to the shore, or coasteering) are likely to result in physical abrasion, addressed above (see abrasion). Therefore, this pressure was considered to be **Not relevant**.

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