Verrucaria mucosa and/or *Hildenbrandia rubra* on upper to mid shore cave walls

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Marine Evidence–based Sensitivity Assessment (MarESA) Review

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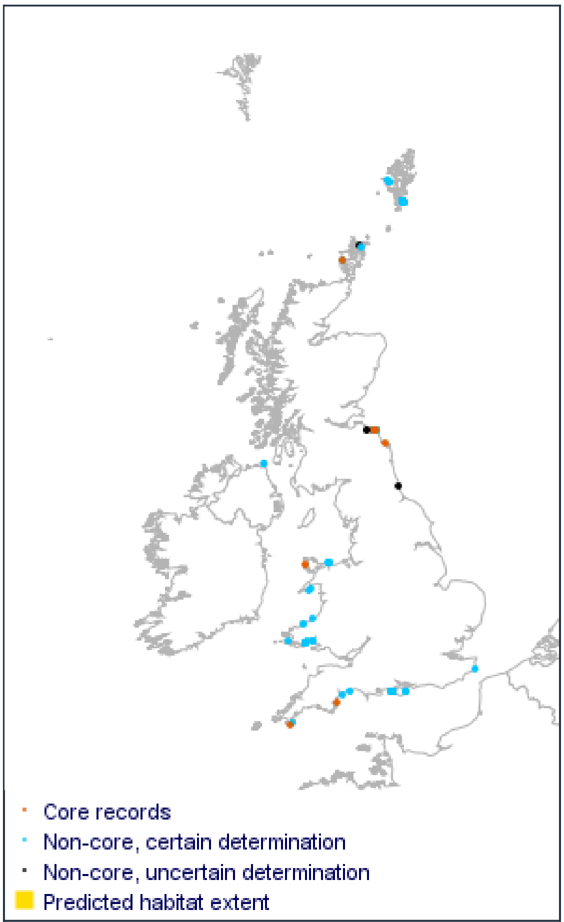

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Dr Harvey Tyler-Walters **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A1.445	*Verrucaria mucosa* and/or *Hildenbrandia rubra* on upper to mid shore cave walls
JNCC 2015	LR.FLR.CvOv.VmucHil	*Verrucaria mucosa* and/or *Hildenbrandia rubra* on upper to mid shore cave walls
JNCC 2004	LR.FLR.CvOv.VmucHil	*Verrucaria mucosa* and/or *Hildenbrandia rubra* on upper to mid shore cave walls
1997 Biotope		

Description

The upper walls and ceilings of the entrances and inner reaches of upper shore caves affected by direct wave action (and therefore moistened by sea spray), characterized by a mosaic of the olive green lichen *Verrucaria mucosa* and the non-calcified encrusting red alga *Hildenbrandia rubra*. The black lichen *Verrucaria maura* and red coralline algae can be present, though not dominating. The fauna in these upper shore caves is generally limited, due to problems of desiccation. However, where conditions remain sufficiently moist, and particularly in crevices and fissures, the barnacle *Semibalanus balanoides*, the limpet *Patella vulgata* and winkles *Littorina saxatilis* may occur, particularly towards the rear of the cave. Although the characterizing species of this biotope also occur on the shore, they do not generally occur in a distinct band other than in moist dark caves. The turf-forming red seaweed *Rhodochorton purpureum* (syn. *Audouinella purpurea*) may occasionally occur in low abundance (where *Rhodochorton purpureum* covers an extensive area, generally on softer rock such as chalk, the biotope should be recorded as RhoCla).

LR.FLR.CvOv.VmucHil generally occurs on upper walls and ceilings towards the rear of dark, moist caves, but can also occur at cave entrances that are directly affected by sea-spray. Where VmucHil occurs at cave entrances and to approximately 5 m into the cave, it is usually found above a zone of Sem and below LR.FLR.CvOvGCv or LR.FLR.CvOvRhoCla. Further into the cave LR.HLR.MusB.Sem is replaced completely by VmucHil. There are no records for VmucHil in soft rock caves. (Information from Connor *et al*., 2004).

Depth range

Upper shore, Mid shore

Additional information

-

Listed By

- none -

Further information sources

Search on:

G G G JNCC

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

Verrucaria mucosa and *Hildenbrandia rubra* form a distinct band on the upper walls and ceilings of moist and dark caves in the mid to upper littoral and littoral fringe. The band is typical of the rear (innermost reaches) of dark moist caves but can occur near the entrance when exposed to adequate spray. Both species occur in the littoral zone but only form a distinct band in cave conditions, presumably because other species of lichen and encrusting algae are less abundant. Other *Verrucaria* spp. may be present and the relative abundance of *Verrucaria mucosa* and *Hildenbrandia rubra* probably varies with location.

The other species present are mobile grazers or occur in low abundance and are typical of other biotopes. In the littoral fringe, littorinids (e.g. *Melarhaphe neritoides* and *Littorina saxatilis*) probably graze the surface of lichens (Fletcher, 1980) and/or the microflora covering rock and other encrusting species. Underwood (1980) observed that grazers had no effect on the recovery of *Hildenbrandia rubra* (as *prototypus*) in cleared areas on a New South Wales shore. While the radula marks of mollusc grazers on the algae were visible they had virtually no effect and were primarily removing microflora from the underlying *Hildenbrandia* (Underwood, 1980). However, Dethier (1994) noted that both *Verrucaria mucosa* and *Hildenbrandia rubra* were eaten by a selection of gastropod grazers under laboratory conditions in Washington, USA. *Verrucaria mucosa* was consumed by two small limpet species while *Hildenbrandia rubra* was one of the preferred algal crusts examined, and was removed by the grazers tested (*Tectura scutum* and *Lottia pelta*), depending on grazing intensity (Dethier, 1994). Fletcher (1980) noted that limpet grazing was noticeable on *Verrucaria mucosa*, ans that in areas of severe limpet grazing, *Verrucaria mucosa* was limited to the upper littoral fringe. However, limpet grazing is probably limited in this littoral fringe biotope. Several species of invertebrate, especially acarid mites, may feed on lichens but they are also highly mobile and found at a range of shore heights (Pugh & King, 1985).

Therefore, both *Verrucaria mucosa* and *Hildenbrandia rubra* have been considered as the important characterizing species for sensitivity assessment. Where relevant, the sensitivity of other species is discussed.

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. 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 (Fletcher, 1980). Dethier & Steneck (2001) recorded a maximum growth rate of 2 mm/year for *Verrucaria mucosa* in the laboratory. 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). 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. Rolan & Gallagher (1991) reported that *Verrucaria* spp. populations were destroyed on the upper shore, 'cleaned' by bulldozing at one site in Sullom voe after the *Esso Bernica* oil spill in 1978. At another site, *Verrucaria maura* was recorded on loose rocks in the littoral, rocks that were presumed to be displaced from the upper shore. Rolan & Gallagher (1991) also reported that lichens recovered within a year or two at four cleared sites, but did not specify the lichen species in question or whether they were littoral or supralittoral species. Crump & Moore (1997) observed that lichens had not colonized experimentally cleared substrata within 12 months. Moore (2006) reported that areas of bare rock (left after rock slices were removed by high-pressure water cleaning) showed no signs of recruitment by *Verrucaria maura* until 6 years after the *Sea Empress* oil spill, and that new colonies had grown to 2 mm in diameter 3 years later (9 years after the spill), and provided 'appreciable cover'. In the absence of any direct evidence to the contrary, the recovery rates of *Verrucaria mucosa* are probably similar to those of *Verrucaria maura*.

Hildenbrandia rubra is a perennial, crustose but non-calcareous red alga. It is recorded from estuaries, harbours, on rocks and caves into the upper littoral down to the sublittoral to depths of at least 12 m. It is recorded from numerous locations worldwide and is probably cosmopolitan (Irvine & Chamberlain, 1994). *Hildenbrandia rubra* grows very slowly in experiments in Washington, USA. For example, Dethier (1994) recorded lateral growth of 1.5 mm in 4 yrs, while Dethier & Steneck (2001) recorded a maximum growth rate of 1.2 mm/yr. Dethier (1994) reported that *Hildenbrandia rubra* was a poor at recruitment, while Underwood (1980) (in New South Wales, Australia) and Peckol & Searles (1983) (North Carolina, USA) reported good recruitment. In clearance experiments in the field, Underwood (1980) noted that *Hildenbrandia rubra* (as *prototypus*) recolonized cleared space by recruitment into small cracks and fissures in the rock surface and subsequent growth as well as growth from existing plants around the edge of the cleared space. In cleared plots, the original cover was reestablished after about 1-1.5 years. Recolonization was retarded by the presence of mature algae (*Ulva*), where 60% cover of *Hildenbrandia rubra* took 20 months to achieve, but it reached 85% cover in areas where macroalgae were already present, indicating that it would eventually reach the same cover in experimentally cleared areas (Underwood, 1980). Similarly, in field clearance experiments in North Carolina, Peckol & Searles (1983), reported that *Hildenbrandia rubra* recruited rapidly to both cleared areas and cement settlement plates in the intertidal and achieved significant cover within two years, except in fall (autumn) due to competition with encrusting bryozoa (*Parasmittina*) and brown algae (*Lobophora*). Peckol & Searles (1983) concluded that recruitment was by spores. Dethier (1994) also suggested that the small cell size of *Hildenbrandia rubra* provided protection from grazing while its ability to regrow filaments from basal cells provided good regenerative capability.

Resilience assessment. The evidence suggests that *Hildenbrandia rubra* can recruit quickly and recover significant loss in cover quickly (1-2 years) even though it has a very slow growth rate. However, *Verrucaria mucosa* grows slightly faster but is likely to take longer to recruit and reestablish. Evidence from Moore (2006) suggests that *Verrucaria maura* recolonize bare rock within 6 years and develop 'appreciable' cover within 9 years. Therefore, assuming *Verrucaria mucosa* is similar, then where its cover is reduced or damaged regrowth is likely, but recovery is likely to take between 2 and 10 years depending on location and assuming growth rates vary. Similarly, it may colonize and reach 'appreciable cover' on bare rock within 10 years. Therefore, a biotope resilience of **Medium** is suggested based on the slower recovery of *Verrucaria mucosa* but with Low confidence.

Hydrological Pressures

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

Fletcher (1980) suggested that the effect of temperature on littoral lichens was inconclusive. For example, *Verrucaria maura* is abundant on both sunny and shaded shores but is considered a shade tolerant plant from north Africa to France and in Scandinavia. Reid (1969; cited in Fletcher, 1980) reported that *Verrucaria mucosa* had the similar temperature resistance to the algae with which it is ecologically associated but that *Verrucaria maura* was even less resistant. However, Fletcher (1980) also suggested that temperature was an important factor for water conservation, in combination with insolation, shade and wind, emersion and precipitation. Dethier (1994) reported that *Verrucaria mucosa* transplanted to a high shore pool consistently died in the summer months. In addition, control transplantations in emergent shaded areas all survived while transplantations into emergent sunny areas all died (Dethier, 1994). This suggests, therefore, that *Verrucosa mucosa* is sensitive to the effect of direct insolation but it is unclear whether this is due to desiccation or temperature. Nevertheless, *Verrucaria mucosa* is recorded from around the coasts of the British Isles, north to Iceland and south to the Cape Verde islands (OBIS 2016), and in Washington State, USA (Dethier, 1994).

Hildenbrandia rubra is found from the littoral fringe down to the subtidal and has a cosmopolitan distribution from Iceland, Alaska and Baffin Bay in the north to South America, South Africa, India and Australia in the south (OBIS, 2016). Kim & Garbary (2006). reported that *Hildenbrandia rubra* was one of the most physiologically tolerant seaweed tested. In laboratory tests, *Hildenbrandia rubra* thalli were exposed to temperatures between -17 to 27°C, from fully hydrated to extremely desiccated, from full seawater to 4 psu and back again over a period of 13 days, without any apparent long-term effects to the photosynthetic apparatus, and no significant difference in photosynthesis (Kim & Garbary, 2006).

Both species are likely to be exposed to a range of temperatures across their range and are probably resistant to temperature change at the benchmark level. Hence, a resistance of **High** is suggested, so that resilience is also **High**, and the biotope is assessed as **Not sensitive** at the benchmark level, albeit with Low confidence.

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

Fletcher (1980) suggested that the effect of temperature on littoral lichens was inconclusive. For example, *Verrucaria maura* is abundant on both sunny and shaded shores but is considered a shade tolerant plant from north Africa to France and in Scandinavia. Reid (1969; cited in Fletcher, 1980) reported that *Verrucaria mucosa* had the similar temperature resistance to the algae with which it is ecologically associated but that *Verrucaria maura* was even less resistant. However, Fletcher (1980) also suggested that temperature was an important factor for water conservation, in combination with insolation, shade and wind, emersion and precipitation. Nevertheless, *Verrucaria mucosa* is recorded from around the coasts of the British Isles, north to Iceland and south to the Cape Verde islands (OBIS, 2016), and in Washington State, USA (Dethier, 1994).

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Both species are likely to be exposed to a range of temperatures across their range and are probably resistant to temperature change at the benchmark level. Hence, a resistance of **High** is suggested, so that resilience is also **High**, and the biotope is assessed as **Not sensitive** at the benchmark level, albeit with Low confidence.

Salinity increase (local)	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

This biotope occurs on the ceilings and walls of caves, depending on their size and degree of wave exposure (and hence spray, and splash) and probably represent an extension of lower littoral fringe and upper littoral into caves. The littoral fringe and upper littoral are likely to experience localised evaporation and resultant increased surface salinity during neap and low tides in hot summers and/or warm windy conditions. However, the cave environment could protect species from wind and insolation (depending on size and aspect) and, hence, protect the habitat from increased salinity due to the evaporation of seawater and spray. Fletcher (1980) noted that marine lichens in the lower littoral fringe died out in waters less than 20‰ while upper littoral fringe lichens were found in waters of 4-20‰ salinity. However, Fletcher (1980) commented that loss of littoral lichens in estuaries can also be attributed to changes in pH, silt, reduced tidal range and reduced wave exposure. Similarly, *Hildenbrandia rubra* is recorded from fully marine and estuarine conditions, as well freshwater seeps (Peckol & Searles, 1983; Irvine & Chamberlain, 1994). Nevertheless, there is not enough evidence to assess their sensitivity to hypersaline conditions.

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

This biotope occurs on the ceilings and walls of caves, depending on their size and degree of wave exposure (and hence spray, and splash) and probably represent an extension of lower littoral fringe and upper littoral into caves. The littoral fringe and upper littoral are likely to experience localised evaporation and resultant increased surface salinity during neap and low tides in hot summers and/or warm windy conditions. However, the cave environment could protect species from wind and insolation (depending on size an aspect) and, hence, protect the habitat from increased salinity due to the evaporation of seawater and spray. Fletcher (1980) noted that marine lichens in the lower littoral fringe died out in waters less than 20‰ while upper littoral fringe lichens were found in waters of 4-20‰ salinity. However, Fletcher (1980) commented that loss of littoral lichens in estuaries can also be attributed to changes in pH, silt, reduced tidal range and reduced wave exposure. Similarly, *Hildenbrandia rubra* is recorded from fully marine and estuarine conditions, as well freshwater seeps (Peckol & Searles, 1983; Irvine & Chamberlain, 1994). Lüning (1990) reported that *Hildenbrandia rubra* was one of a few algae that could survive mesohaline (18-8‰) conditions. Kim & Garbary (2006) reported that *Hildenbrandia rubra* was one of the most physiologically tolerant seaweed tested. In laboratory tests, *Hildenbrandia rubra* thalli were exposed to temperatures between -17 to 27°C, from fully hydrated to extremely desiccated, from full seawater to 4 psu and back again over a period of 13 days, without any apparent long-term effects to the photosynthetic apparatus, and no significant difference in photosynthesis (Kim &

Garbary, 2006).

Overall, a reduction from 'full' to 'reduced' salinity may result in loss of a proportion of the *Verrucaria mucosa* population in the upper intertidal while *Hildenbrandia rubra* is probably resistant. As this biotope occurs in shaded, moist caves and can extend to the ceilings of caves, its inundation and emergence are probably highly variable between caves. Therefore, a resistance of **Medium** is suggested to represent the loss of the proportion of the population of *Verrucaria mucosa* most exposed to inundation. Resilience is probably **Medium** so that a sensitivity of **Medium** is recorded.

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

Tidal influence in mid-littoral to supralittoral caves is probably is probably limited to the floor and sides of the caves, and the upper walls and ceilings only receive spray and splash. However, water movement, splash, spray in caves are probably wave mediated rather than due to tidal streams. Therefore, the biotope is unlikely to be affected by water flow as described by the benchmark and the pressure is **Not relevant**.

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

Fletcher (1980) noted that littoral lichens are emersed for several weeks during neap tides, during which time they are exposed to the hottest and dryest periods in summer and the coldest and most frost-prone periods in winter. The levels of moisture and relative duration of wet and dry periods are the most important factors controlling vertical zonation in marine lichens. Rates of evaporation and hence desiccation is dependent on 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 littoral lichen communities.

- Littoral lichens lost water faster than they absorbed it, over periods of up to 200 hrs, but that the reverse was true of supralittoral species (Fletcher, 1980).
- *Verrucaria mucosa* is less efficient at water conservation than *Verrucaria maura* (which occurs higher on the shore, but can occur in this biotope) (Fletcher, 1980).
- *Verrucaria maura* is the only littoral lichen species found above the littoral fringe, although it is restricted to crevices that retain water (Fletcher, 1980).
- Littoral lichens were able to maintain photosynthesis after 35 days of immersion.
- All littoral species needed to be 30-50% water saturated for respiration and 40% saturated for photosynthesis but achieved maximum photosynthesis at 100% saturation.
- Fletcher (1976; cited in Fletcher, 1980) found no difference in photosynthesis and respiration between *Verrucaria maura* and *Verrucaria mucosa* after two days of drought at 0% relative humidity but that the littoral lichens died quickly when exposed to cycles of 21 hr drought, and 3 days submersion over a period of 14 days.
- Dethier (1994) reported that *Verrucaria mucosa* transplanted to a high shore pool consistently died in the summer months. In addition, control transplantations in emergent shaded areas all survived while transplantations into emergent sunny areas all died (Dethier, 1994). This suggests, therefore, that *Verrucosa mucosa* is sensitive to the effect of

direct insolation but it is unclear whether this is due to desiccation or temperature.

Dethier (1994) also noted that *Hildenbrandia rubra* was tolerant of a range of intertidal stresses, and survived in high emergent rock and in' desiccated mid-south areas' but that it grew more slowly when transplanted to the highest zones examined and experienced only partial mortality compared to the other algal crusts tested. Kim & Garbary (2006) reported that *Hildenbrandia rubra* was one of the most physiologically tolerant seaweed tested. In laboratory tests, *Hildenbrandia rubra* thalli were exposed to temperatures between -17 to 27°C, from fully hydrated to extremely desiccated, from full seawater to 4 psu and back again over a period of 13 days, without any apparent long-term effects to the photosynthetic apparatus, and no significant difference in photosynthesis (Kim & Garbary, 2006).

Sensitivity assessment. Water relations (Fletcher 1980) are vital to the zonation of marine lichens and *Hildenbrandia rubra* is limited to the upper littoral and littoral fringe. In this cave biotope, the shape and aspect of the cave presumably allows the wave surge, splash and spray to reach a greater height depending on exposure and emergence while providing protection from wind and insolation, so that the evaporation is reduced and moisture (humidity) is high, relative open rock. A decrease in emersion (increased inundation) would probably allow the biotope to extend up to ceilings of caves, where suitable substratum exists. However, the lower littoral fringe would probably be lost to competition from macroalgae (see CvOv.AudCla) or barnacles, depending on the exposure of the shore. Conversely, an increase in emersion (reduced inundation) would probably result in loss of the upper limit of the biotope belt and its replacement by green algal films (see CvOv.GCv). Therefore, a decrease in emersion is likely to result is a slow shift in the biotope up the shore but an increase in emergence is likely to result in a rapid loss of *Verrucaria* spp. at its upper limit, based on observations by Fletcher (1976; cited in Fletcher, 1980). Hence, a resistance of **Low** is suggested. As resilience is probably **Medium**, a sensitivity of **Medium** is recorded.

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

This biotope reaches upper walls and ceilings of caves directly affected by wave action (Connor *et al*., 2004), where wave surge, splash and spray keep the rock surface moist. It is recorded from caves that experience moderately wave exposed and wave exposed conditions. Therefore, an increase in wave exposure may increase the extent of the biotope, but a decrease in wave exposure is likely to result in loss of extent. However, a 3-5% change in significant wave height is unlikely to be significant in wave exposed conditions. Therefore, the biotope is probably **Not sensitive** (resistance and resilience are **High**) at the benchmark level.

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). No information on the effects of heavy metals on *Hildenbrandia rubra* 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 marine lichen communities, although in many cases is difficult to separate the effects of oiling from the effects of dispersants.

- Ranwell (1968) noted that *Verrucaria maura* and *Verrucaria mucosa* were killed after the *Torrey Canyon'* due to oiling but especially emulsifiers (Kerosene based).
- Cullinane *et al.* (1975) reported that oil was absorbed onto the thallus of *Verrucaria mucosa* but not onto the surrounding crust of *Hildenbrandia* spp. after the oil spill in Bantry Bay and concluded that gelatinous (e.g. *Verrucaria mucosa*) or non-crustose lichens absorb oil and were easily damaged.
- Oiling and subsequent clean up cause loss of (unspecified) lichen cover after the *Sea Empress* oil spill (Moore, 2006) but noted that high pressure washing did not kill *Verrucaria maura.*

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. 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 (see Hydrocarbon and PAH contamination above). But no information on *Hildenbrandia* spp. was found.

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

In this cave biotope, the shape and aspect of the cave presumably allow wave surge, splash and spray to reach a greater height depending on exposure and emergence while providing protection from wind and insolation, so that the evaporation is reduced and moisture (humidity) is high, relative open rock. The biotope is probably an extension of the lower littoral fringe. The littoral fringe is is rarely inundated and is often exposed to the air. For example, Fletcher (1980) noted that *Lichina confinis*, a species that occurs at the top of the littoral fringe, spent a maximum of 1% of time submerged each year while *Verrucaria striatula*, a species that occurs in the lower littoral fringe below the *Verrucaria maura*, spent a maximum of 44% of time submerged each year. Therefore, this biotope is probably exposed to the air for the majority of the time. Even if the water lapping over the littoral fringe was deoxygenated, wave action and turbulent flow over the rock surface would probably aerate the water column. Hence, the biotope is unlikely to be exposed to deoxygenated conditions and the pressure is assessed as 'Not relevant.

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 (Fletcher, 1980) but the evidence of the importance of nutrient in the in the littoral fringe is less clear. Wootton (1991) examined the effects of bird guano on rocky shore lichens in the San Juan archipelago, Washington. *Verrucaria mucosa* cover declined in areas affected by guano but the decline was only significant in wave exposed sites where the cover of *Prasiola meridionalis* increased. Connor *et al.* (2004) noted that *Prasiola* and opportunistic algae (e.g. *Ulva* and *Porphyra*) grow over the *Verrucaria* belt in the intertidal. In dark moist caves, while the moisture may allow *Prasiola* or other opportunitic algae to grow, the light regime may restrict their growth. However, no evidence on the effects on *Hildenbrandia rubra* was found. Nevertheless, 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	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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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 lichen and algal crust community typical of this biotope is only found on hard substrata. This biotope is not recorded from chalk. 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	Medium Q: Low A: NR C: NR	Medium Q: Low A: NR C: NR	Medium Q: Low A: Low C: Low

Fletcher (1980) reported that the species diversity of lichens decreased in areas subject to mechanical damage, such as trampling, the passage of boats or vehicles, mining or physical removal due to building works. In disturbed areas, the 'normal' lichen flora is replaced by disturbance tolerant species, typically faster-growing species. For example, the littoral zone is dominated by *Arthopyrenia halodytes* in disturbed areas (Fletcher, 1980). Dethier (1994) noted that *Verrucaria mucosa* was less susceptible to experimental brushing with 'steel brush' than other crustose species in the littoral, but that it became more susceptible to damage from a steel and a nylon brush when completely submerged. *Hildenbrandia rubra* was negatively affected by steel brushing in the field but lost less area than any other crust tested, other than the Petrocelis phase of *Mastocarpus* (Dethier (1994). In the laboratory, *Hildenbrandia rubra* it was one of the most resistant crusts tested (Dethier 1994).

Verrucaria maura was not killed by high pressure washing during the *Sea Empress* oil spill clean-up (Moore, 2006) but *Verrucaria* spp. was removed by bulldozing of the shore after the *Esso Bernica* oil spill (Rolan & Gallagher, 1991), although it was removed because the surface of the rock itself was removed or damaged.

Sensitivity assessment. There is little direct evidence on the effect of surface abrasion as described by the pressure definition on this biotope or its characteristic species. Both *Verrucaria mucosa and Hildenbrandia rubra are* crustose and closely adherent to the rock surface so may resist abrasion and only be removed where the abrasion destroys the rock surface. The work of Dethier (1994) suggests that abrasion (e.g. by chains or cables) may be detrimental. However, the observation that fast growing lichen species come to dominate areas subject to disturbance (Fletcher, 1980) suggests that the biotope may be sensitive. Gastropods would probably be removed by abrasion and barnacle crushed, except where they occur in crevices. Overall, a resistance of **Medium** is suggested to represent localised damage of the rock surface or long-term abrasion and disturbance but with **Low** confidence. As resilience is probably **Medium** and sensitivity assessment of **Medium** is recorded.

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

This biotope occurs in mid to upper littoral and littoral fringe and reaches upper walls and ceilings of caves, probably only exposed to wave splash and rarely inundated. For example, Fletcher (1980) noted that *Lichina confinis*, a species that occurs at the top of the littoral fringe, spent a maximum of 1% of time submerged each year while *Verrucaria striatula*, a species that occurs in the lower littoral fringe below the *Verrucaria maura*, spent a maximum of 44% of time submerged each year. Therefore, an increase in turbidity due to suspended solids (at the benchmark) is unlikely to adversely affect the biotope and **Not relevant** is recorded.

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

The ceilings and upper, vertical walls of caves are unlikely to be subject to smothering, but the inner reaches of caves with shallow slopes or horizontal ledges may be. In the wave exposed conditions experienced by this biotope, 5 cm of sediment may be removed quickly from the entrance but may persist in the inner reaches of the cave, depending on the shape of the cave.

Algal crusts are considered to dominate in areas of disturbance, grazing or sand scour. In experiments, *Hildenbrandia occidentalis* was partially covered by an opaque disk (Dethier & Steneck, 2001). It persisted 'remarkably well', paled slightly and showed only a small reduction in growth after one year. Dethier & Steneck (2001) reported that *Hildenbrandia* spp. was found under barnacles and mussels that were several years old. In similar experiments, Underwood (2006)

Hildenbrandia rubra crusts covered partially or completely by black discs showed reduced growth, but the reduction was greatest when its thallus was separated from any unshaded thallus. However, after 13 months the crusts were alive in all plots even with a reduction in area of 44-98%. It was only eliminated in one site (Underwood, 2006). Underwood (2006) noted that *Hildenbrandia rubra* crusts could withstand overgrowth for some considerable time. In field experiments, crusts of *Hildenbrandia rubra* overgrown by foliose algae still had 55-65% cover (compared to 80-90% cover in controls) after 18 months (Underwood, 1980, 2006). Fletcher (1980) noted that littoral fringe lichens die back in estuarine conditions but that loss of littoral lichens in estuaries could also be attributed to changes in salinity, pH, silt, reduced tidal range or reduced wave exposure.

Sensitivity assessment. The above evidence suggests that *Hildenbrandia rubra* would survive smothering by 5 cm of sediment, and it is probably resistant of scour. The loss of littoral fringe lichens in estuaries suggests that siltation, scour or smothering may be involved, but is inconclusive. In wave exposed conditions, if the smothering sediment is removed quickly, then *Verrucaria mucosa* would probably survive. Therefore, a resistance of **High** is suggested but with **Low** confidence. Therefore, resilience is recorded as **High** and the biotope is probably **Not sensitive** at the benchmark level.

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

The ceilings and upper, vertical walls of caves are unlikely to be subject to smothering, but the inner reaches of caves with shallow slopes or horizontal ledges may be. A deposit of 30 cm of fine sediment in caves is likely to remain in place for some time, depending on the degree of wave exposure. In the wave exposed conditions experienced by this biotope, 30 cm of sediment may be removed quickly from the entrance but may persist in the inner reaches of the cave.

Algal crusts are considered to dominate in areas of disturbance, grazing or sand scour. In experiments, *Hildenbrandia occidentalis* was partially covered by an opaque disk (Dethier &Steneck, 2001). It persisted ‘remarkably well’, paled slightly and showed only a small reduction in growth after one year. Dethier & Steneck (2001) reported that *Hildenbrandia* spp. was found under barnacles and mussels that were several years old. In similar experiments, Underwood (2006) *Hildenbrandia rubra* crusts covered partially or completely by black discs showed reduced growth, but the reduction was greatest when its thallus was separated from any unshaded thallus. However, after 13 months the crusts were alive in all plots even with a reduction in area of 44-98%. It was only eliminated in one site (Underwood, 2006). Underwood (2006) noted that *Hildenbrandia rubra* crusts could withstand overgrowth for some considerable time. In field experiments, crusts of *Hildenbrandia rubra* overgrown by foliose algae still had 55-65% cover (compared to 80-90% cover in controls) after 18 months (Underwood, 1980, 2006). Fletcher (1980) noted that littoral fringe lichens die back in estuarine conditions but that loss of littoral lichens in estuaries could also be attributed to changes in salinity, pH, silt, reduced tidal range or reduced wave exposure.

Sensitivity assessment. The above evidence suggests that *Hildenbrandia rubra* would survive smothering by 5 cm of sediment, and it is probably resistant of scour. The loss of littoral fringe lichens in estuaries suggests that siltation, scour or smothering may be involved, but is inconclusive. Therefore, a resistance of **Medium** (<25% loss) is suggested to represent to the potential loss of *Verrucaria mucosa* from this biotope but with **Low** confidence. Therefore, resilience is recorded as **Medium** and sensitivity 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

Not assessed. Caves, especially high on the shore, may accumulate litter blown into the cave by the wind. Large pieces of marine debris blown around by wind or wave action may cause abrasion of the cave wall communities (see above). However, **No evidence** on the effects of litter was found.

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

No evidence 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

Not relevant

Introduction of light or shading	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

This biotope occurs at the entrances of wave exposed caves and forms a distinct band in dark moist conditions. Fletcher (1980) noted that *Verrucaria mucosa* appeared black in sunlit areas but green in shaded areas, was black in summer and olive-green in winter, and that is increased in abundance on shaded shores, even in areas of wave exposure.

In experiments, *Hildenbrandia occidentalis* was partially covered by an opaque disk (Dethier &Steneck, 2001). It persisted 'remarkably well', paled slightly and showed only a small reduction in growth after one year. Dethier & Steneck (2001) reported that *Hildenbrandia* spp. was found under barnacles and mussels that were several years old. In similar experiments, Underwood (2006) *Hildenbrandia rubra* crusts covered partially or completely by black discs showed reduced growth, but the reduction was greatest when its thallus was separated from any unshaded thallus. However, after 13 months the crusts were alive in all plots even with a reduction in area of 44-98%. It was only eliminated in one site (Underwood, 2006). Underwood (2006) noted that *Hildenbrandia rubra* crusts could withstand overgrowth for some considerable time. In field experiments, crusts of *Hildenbrandia rubra* overgrown by foliose algae still had 55-65% cover (compared to 80-90% cover in controls) after 18 months (Underwood, 1980, 2006). Therefore, *Hildenbrandia rubra* is unlikely to be affected by shading.

Sensitivity assessment. The biotope is probably unaffected by shading (although a complete absence of light is detrimental to all algae and lichens). An increase in sunlight may be detrimental but no evidence on the effect of artificial lighting in littoral caves was found. In terrestrial caves know for their archaeology artificial lights contribute to the increase in green algal growth but their environment is probably very different. Therefore, a resistance of **High** is recorded, so that resilience is **High** and the biotope is probably **Not sensitive** to this pressure.

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

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 caves, 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

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 or algal crusts 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. Similarly, not information on non-native algal crustose species was found. 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

Extraction of lichen and algal crusts will undoubtedly reduce their abundance. But given their thin, encrusting and adherent form, extraction is unlikely. However, **No evidence** of 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

Verrucaria spp. are crustose lichens and *Hildenbrandia rubra* is a crustose algae; both are thin and closely attached to the suface of hard rocks. It is very unlikely that they would be removed accidentally by any fishery activity at a commercial or recreational scale. Physical removal from rock by abrasion, or by removal of pieces of rock could occur during oil spill cleanup by high pressure washing or bulldozing (Rolan & Gallagher, 1991; Moore, 2006) but physical abrasion is addressed under the relevant pressure above. Therefore, this pressure was considered to be **Not relevant**.

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