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Marine Information Network

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

Verrucaria maura and sparse barnacles on exposed littoral fringe rock

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

Dr Harvey Tyler-Walters

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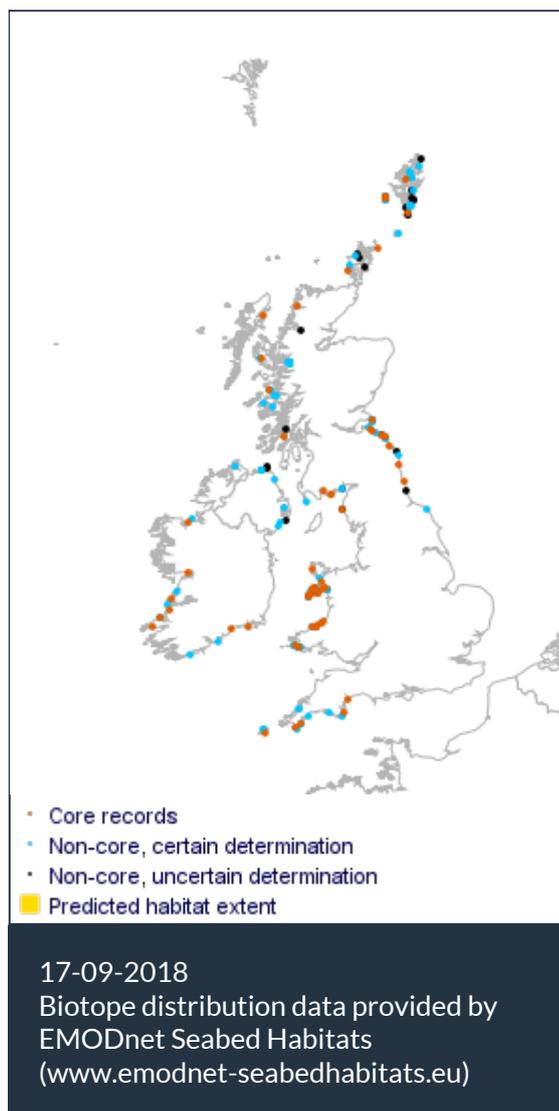
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Verrucaria maura and sparse barnacles on exposed littoral fringe rock

Photographer: Keith Hiscock

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Researched by Dr Harvey Tyler-Walters

Refereed by This information is not refereed.

Summary

☰ UK and Ireland classification

EUNIS 2008	B3.1131	<i>Verrucaria maura</i> and sparse barnacles on exposed littoral fringe rock
JNCC 2015	LR.FLR.Lic.Ver.B	<i>Verrucaria maura</i> and sparse barnacles on exposed littoral fringe rock
JNCC 2004	LR.FLR.Lic.Ver.B	<i>Verrucaria maura</i> and sparse barnacles on exposed littoral fringe rock
1997 Biotope	LR._L.Ver.B	<i>Verrucaria maura</i> and sparse barnacles on exposed littoral fringe rock

🔍 Description

The littoral fringe of very exposed to moderately exposed rocky shores with a sparse covering of the barnacles *Semibalanus balanoides* and/or *Chthamalus montagui* over the black lichen *Verrucaria maura*. Winkles *Littorina saxatilis* and *Melarhaphe neritoides* are usually present although *Melarhaphe*

neritoides tends to be found on more exposed shores. The limpet *Patella vulgata* is often present though at a low abundance. This biotope can be dominated by ephemeral seaweeds including the red seaweed *Porphyra umbilicalis*, the green seaweeds *Ulva* spp. or, particularly in the north, microscopic blue-green algae (Cyanophyceae), which overgrow *Verrucaria maura*. The wrack *Pelvetia canaliculata* may also be present, becoming increasingly more common with greater shelter (see Pel.B). On northern and eastern shores the barnacle is usually *Semibalanus balanoides*, which is normally restricted to the lower littoral fringe, with a band of *Verrucaria maura* only in the upper littoral fringe. On south-west and western shores the barnacle is usually *Chthamalus montagui* which may extend over the whole of the littoral fringe zone.

This biotope (Ver.B) is usually found on more exposed coasts below the *Verrucaria maura* biotope Ver.Ver. It is found above the mussel *Mytilus edulis* and barnacles biotope (MytB) or above the barnacle and *Patella* spp. zone (Cht.Cht; Sem). Ver.B also occurs on vertical faces of moderately exposed shores where the *Pelvetia canaliculata* biotope (PelB) usually dominates on non-vertical faces. The abundance of *Porphyra umbilicalis* shows considerable seasonal and geographical variation. During warm weather *Porphyra umbilicalis* is often bleached light brown and sticks to the rock as it dries out. On southern shores it may be absent during the summer on all but the most exposed shores, as it dies back leaving the barnacle and lichen dominated community. In the cooler north the *Porphyra umbilicalis* covering persists throughout the year. *Porphyra linearis* can also be found in the among the *Porphyra umbilicalis* during the late winter and spring. (Information adapted from Connor *et al.*, 2004; JNCC, 2015).

↓ Depth range

Upper shore

🏛️ Additional information

-

✓ Listed By

- none -

🔗 Further information sources

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Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The biotope LR.FLR.Lic.Ver and its sub-biotopes LR.FLR.Lic.Ver.Ver and LR.FLR.Lic.Ver.B are characterized by the abundance of the black lichen *Verrucaria maura*. A significant reduction in the abundance of *Verrucaria maura*, or its loss, would result in loss of the biotopes. *Littorina saxatilis* is also a characterizing species but it is mobile, not dependent on *Verrucaria maura* for habitat, and common in the upper to lower littoral fringe, the upper eulittoral and upper shore rockpools and crevices. If *Littorina saxatilis* was removed it would probably return quickly. Similarly, many of the macroalgae that occur are transient or opportunistic (e.g. *Porphyra* spp., *Ulva* spp.) and the gastropod fauna are mobile (e.g. *Patella*) or restricted to crevices (e.g. *Melarhappe neritoides*). Kronberg (1988) recorded numerous species from the littoral 'black' zone in Europe but noted that the communities were generally species-poor and that most species were mobile, feeding in the 'black' zone temporally, before returning to the more marine or terrestrial regions of origin or to refuges in crevices. Therefore, *Verrucaria maura* is the only species required to recognize the biotopes (Ver and Ver.Ver). However, the barnacles (*Semibalanus balanoides* and/or *Chthamalus montagui*) that characterize Ver.B reach their upper shore limit in Ver.B and are probably more sensitive to change in this biotope than in barnacle dominant biotopes. If the barnacles were removed or lost then the Ver.B biotope would be replaced by Ver or Ver.Ver and the Ver.B biotope would be lost based on the habitat classification. Therefore, the sensitivity of the Ver.B biotope is based on the sensitivity of *Verrucaria maura* and the resident barnacles (*Semibalanus balanoides* and/or *Chthamalus montagui*).

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. 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). 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). 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 temperate, 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'.

The lifespan of *Chthamalus* spp. is 10+ years (Mieszkowska *et al.*, 2014). Sexual maturity can be reached in the first year and a number of broods may be produced each year. Burrows *et al.* (1992) found that the number of eggs per brood of *Chthamalus stellatus* ranged between 1,274 - 3,391 in Britain, depending on body size and weight. Shore height affects a number of life history parameters. Growth is more rapid and the mortality rate is greater lower down on the shore (Southward & Crisp, 1950). Towards the northern limits of distribution annual recruitment is low (Kendall & Bedford, 1987) and they have an increased longevity (Lewis, 1964). Burrows *et al.* (1992) found that the fecundity generally increased with lower shore levels colonized, with estimates of 1-2 broods per year at high shore levels, 2 to over three at mid shore levels and over 2 to over 4 at low shore levels. Southward (1978) suggested that *Chthamalus montagui* breeds one to two months later than *Chthamalus stellatus*. However, Crisp *et al.* (1981) found little difference in SW Britain, with the main breeding peak in June and August (O'Riordan *et al.*, 1995). Throughout the breeding season, most individuals produce several broods (Burrows *et al.*, 1992; O'Riordan *et al.*, 1992), with a small percentage of the population remaining reproductively active throughout the year (O'Riordan *et al.*, 1995; Barnes, 1989).

On rocky shores, barnacles are often quick to colonize available gaps. Bennell (1981) observed that barnacles that were removed when the surface rock was scraped off in a barge accident at Amlwch, North Wales returned to pre-accident levels within 3 years. Petraitis & Dudgeon (2005) also found that *Semibalanus balanoides* quickly recruited (present a year after and increasing in density) to experimentally cleared areas within the Gulf of Maine, which had previously been dominated by *Ascophyllum nodosum*. However, barnacle densities were fairly low (on average 7.6% cover) and predation levels in smaller patches were high (Petraitis *et al.*, 2003). Local environmental conditions, including surface roughness (Hills & Thomason, 1998), wind direction (Barnes, 1956), shore height, wave exposure (Bertness *et al.*, 1991) and tidal currents (Leonard *et al.*, 1998) have been identified, among other factors, as factors affecting settlement of *Semibalanus balanoides*. Biological factors such as larval supply, competition for space, the presence of adult barnacles (Prendergast *et al.*, 2009) and the presence of species that facilitate or inhibit settlement (Kendall *et al.*, 1985, Jenkins *et al.*, 1999) also play a role in recruitment. Mortality of juveniles can be high but highly variable, with up to 90% of *Semibalanus balanoides* dying within ten days (Kendall *et al.*, 1985). Presumably, these factors would also influence the transport, supply and settlement of *Chthamalus* spp. larvae.

Resilience assessment. Mobile invertebrate fauna and opportunistic macroalgae will probably recolonize rapidly. The above evidence suggests that barnacles would recover within a few years. Their abundance in this biotope is only occasional (ca < 10%) so that a single recruitment event may be enough to repopulate the habitat. Hence, the resilience of barnacles in this biotope is probably 'High' even if removed or lost (resistance is 'Low' or Very low'). Little information on recovery in *Verrucaria maura* was found, although if similar to *Verrucaria mucosa* (a maximum of 2 mm/year), growth is slow. Evidence from Moore (2006) suggests that *Verrucaria maura* can recolonize bare rock within 6 years and develop 'appreciable' cover within 9 years. Where the cover of *Verrucaria maura* 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, the resilience of the biotope as a whole would be assessed as **Medium**. However, although the Ver.B. biotope is characterized by *Verrucaria maura* cover and bare rock, Ver and Ver.Ver are characterized by almost complete cover.

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: Medium A: Low C: Low

Marine 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, precipitation, sunlight and shading. 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.

This biotope may contain a mix of *Chthamalus* and *Semibalanus balanoides* barnacles depending on location. Increased temperatures are likely to favour chthamalid barnacles (that dominate the south and south-west examples of this biotope) rather than *Semibalanus balanoides* (that dominates northern and eastern examples of this biotope) (Southward *et al.* 1995; Connor *et al.*, 2004). Long-term time series show that successful recruitment of *Semibalanus balanoides* is correlated to sea temperatures (Mieszkowska *et al.*, 2014) and that, due to recent warming, its range has been contracting northwards. Temperatures above 10 to 12°C inhibit reproduction (Barnes, 1957, 1963, Crisp & Patel, 1969) and laboratory studies suggest that temperatures at or below 10°C for 4-6 weeks are required in winter for reproduction, although the precise threshold temperatures for reproduction are not clear (Rognstad *et al.*, 2014). Observations of recruitment success in *Semibalanus balanoides* throughout the south-west of England, strongly support the hypothesis that an extended period (4-6 weeks) of sea temperatures <10°C is required to ensure a good supply of larvae (Rognstad *et al.*, 2014, Jenkins *et al.*, 2000). During periods of high reproductive success, linked to cooler temperatures, the range of barnacles has been observed to increase, with range extensions in the order of 25 km (Wethey *et al.*, 2011) and 100 km (Rognstad *et al.*, 2014). Increased temperatures are likely to favour chthamalid barnacles rather than *Semibalanus balanoides* (Southward *et al.*, 1995). *Chthamalus montagui* and *Chthamalus stellatus* are warm water species, with a northern limit of distribution in Britain so are likely to be tolerant of long-term increases in temperature. The range of *Chthamalus stellatus* and *Chthamalus montagui* has been extending northwards due to increasing temperatures. Breeding of *Chthamalus stellatus* in France occurs in April (Barnes, 1992), and correlates with mean air and sea temperatures of 11 - 12°C, and maximum temperatures of 14 °C. Barnes (1992) found that at an upper-temperature limit of 20 - 21°C in the sea and 24 - 25°C in the air reproductive activity decreased. *Chthamalus* suffers a failure of fertilization at temperatures of 9°C and below (Patel & Crisp, 1960), its lower critical

temperature for feeding activity is 4.6°C (Southward, 1955). *Semibalanus balanoides* out-competes *Chthamalus* species for space, but recruitment declines and failures of *Semibalanus balanoides* in response to warmer temperatures benefit *Chthamalus* species by allowing them to persist and recruit (Mieszkowska *et al.*, 2014).

Sensitivity assessment. The 'black lichen zone' (Ver) experiences the extremes of hot summers and cold frosty winters and is, therefore, adapted to extreme variation in temperature. It also occurs from North Africa to Scandinavia, so that it is unlikely to be adversely affected by changes in temperature at the benchmark level within Britain and Ireland. Similarly, chronic or acute change at the benchmark level may affect reproduction and survival or the difference barnacle species and affect the relative abundance of *Semibalanus* or *Chthamalus*. However, the biotope will remain as long as one of the characteristic barnacle species remains. 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 littoral species was found. Similarly, longer-term, broad-scale perturbations such as increased temperatures from climate change might have a greater effect on the relative abundance of the characteristic barnacles.

Temperature decrease (local)

High

Q: Medium A: Low C: Low

High

Q: High A: High C: High

Not sensitive

Q: Medium A: Low C: Low

Marine 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, precipitation, sunlight and shading. 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.

This biotope may contain a mix of *Chthamalus* and *Semibalanus balanoides* barnacles depending on location. Decreased temperatures are likely to favour *Semibalanus balanoides* (that dominates northern and eastern examples of this biotope) rather than chthamalid barnacles (that dominate the south and south-west examples of this biotope) (Southward *et al.* 1995; Connor *et al.*, 2004). Long-term time series show that successful recruitment of *Semibalanus balanoides* is correlated to sea temperatures (Mieszkowska *et al.*, 2014) and that, due to recent warming, its range has been contracting northwards. Temperatures above 10 to 12°C inhibit reproduction (Barnes, 1957, 1963, Crisp & Patel, 1969) and laboratory studies suggest that temperatures at or below 10°C for 4-6 weeks are required in winter for reproduction, although the precise threshold temperatures for reproduction are not clear (Rognstad *et al.*, 2014). Observations of recruitment success in *Semibalanus balanoides* throughout the south-west of England, strongly support the hypothesis that an extended period (4-6 weeks) of sea temperatures <10°C is required to ensure a good supply of larvae (Rognstad *et al.*, 2014, Jenkins *et al.*, 2000). During periods of high reproductive

success, linked to cooler temperatures, the range of barnacles has been observed to increase, with range extensions in the order of 25 km (Wetthey *et al.*, 2011), and 100 km (Rognstad *et al.*, 2014). The barnacle *Semibalanus balanoides* has a greater tolerance for cooler temperatures and a decrease in temperature may enhance recruitment success and replacement of *Chthamalus* spp. The tolerance of *Semibalanus balanoides* collected in the winter (and thus acclimated to lower temperatures) to low temperatures was tested in the laboratory. The median lower lethal temperature tolerance was -14.6°C (Davenport & Davenport, 2005). *Chthamalus montagui* and *Chthamalus stellatus* are warm water species, with a northern limit of distribution in Britain so are likely to be tolerant of long-term increases in temperature. The range of *Chthamalus stellatus* and *Chthamalus montagui* has been extending northwards due to increasing temperatures. Breeding of *Chthamalus stellatus* in France occurs in April (Barnes, 1992), and correlates with mean air and sea temperatures of $11 - 12^{\circ}\text{C}$, and maximum temperatures of 14°C . Barnes (1992) found that at an upper-temperature limit of $20 - 21^{\circ}\text{C}$ in the sea and $24 - 25^{\circ}\text{C}$ in the air reproductive activity decreased. *Chthamalus* suffers a failure of fertilization at temperatures of 9°C and below (Patel & Crisp, 1960), its lower critical temperature for feeding activity is 4.6°C (Southward, 1955). The cold winter of 2009-10 in France led to recruitment failure in *Chthamalus* species (Wetthey *et al.*, 2011). *Semibalanus balanoides* out-competes *Chthamalus* species for space, but recruitment declines and failures of *Semibalanus balanoides* in response to warmer temperatures benefit *Chthamalus* species by allowing them to persist and recruit (Mieszkowska *et al.*, 2014).

Sensitivity assessment. The 'black lichen zone' (Ver) experiences the extremes of hot summers and cold frosty winters and is, therefore, adapted to extreme variation in temperature. It also occurs from North Africa to Scandinavia, so that it is unlikely to be adversely affected by changes in temperature at the benchmark level within Britain and Ireland. Similarly, chronic or acute change at the benchmark level may affect reproduction and survival or the difference barnacle species and affect the relative abundance of *Semibalanus* or *Chthamalus*. However, the biotope will remain as long as one of the characteristic barnacle species remains. 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 littoral species was found.

Salinity increase (local)	Not relevant (NR)	Not relevant (NR)	No evidence (NEv)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

The littoral fringe is likely to experience localised evaporation and a resultant increase in surface salinity during neap and low tides in hot summers and/or warm windy conditions. 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. Barnes & Barnes (1974) found that larvae from six barnacle species including *Chthamalus stellatus* and *Semibalanus (as Balanus) balanoides*, completed their development to nauplii larvae at salinities between 20-40‰ and some embryos exposed at later development stages could survive at higher and lower salinities.

Overall, littoral lichens receive regular inundation by seawater, unlike the supralittoral, and may not experience the extremes of salt spray. Nevertheless, there is not enough evidence to assess the sensitivity of the biotope to hypersaline conditions.

Salinity decrease (local)**Low**

Q: Low A: Low C: Low

Medium

Q: Medium A: Medium C: Medium

Medium

Q: Low A: Low C: Low

The littoral fringe is likely to experience localised evaporation and a resultant increase in surface salinity during neap and low tides in hot summers and/or warm windy conditions. Conversely, it is exposed to rainfall and freshwater runoff during low and neap tides. 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.

Barnes & Barnes (1974) found that larvae from six barnacle species including *Chthamalus stellatus* and *Semibalanus (as Balanus) balanoides*, completed their development to nauplii larvae at salinities between 20-40‰ and some embryos exposed at later development stages could survive at higher and lower salinities. Barnes & Barnes (1965) found that in high suspended solids and low salinity there was a decrease in the number of eggs per brood of *Chthamalus stellatus* / *Chthamalus montagui*. If salinities decrease below 21 psu all cirral activity of barnacles normally associated with full salinity waters, ceases (Foster, 1971b). *Semibalanus balanoides* are tolerant of a wide range of salinity and can survive periodic emersion in freshwater, e.g. from rainfall or freshwater run-off, by closing their opercular valves (Foster, 1971b). They can also withstand large changes in salinity over moderately long periods of time by falling into a "salt sleep" and can be found on shores (example from Sweden) with large fluctuations in salinity around a mean of 24 (Jenkins *et al.*, 2001).

Sensitivity assessment. The characteristic barnacles are probably adapted to changes in salinity. Hence, a reduction from full to reduced salinity may result in some mortality (resistance is 'Medium'), although recovery is probably rapid (resilience is 'High'). However, the limited evidence suggests that littoral lichens would be adversely affected by a reduction of salinity and a resistance of 'Low' is suggested but at 'Low' confidence. Resilience is probably 'Medium', therefore, 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

The littoral fringe 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**Low**

Q: High A: High C: Medium

Medium

Q: Medium A: Medium C: Medium

Medium

Q: Medium A: Medium C: Medium

The emergence regime, that is the time covered or uncovered by the tide, is likely to change the frequency of drying and wetting of lichens, especially on sheltered shores. Fletcher (1980) noted that littoral lichens are emersed for several weeks during neap tides, during which time they are exposed to the hottest and driest 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* (which occurs lower on the shore) is less efficient at water conservation than *Verrucaria maura* (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 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.

Some regional variation occurs in the distribution of *Chthamalus* on the shore and its vertical zonation will be affected by wave splash and shore steepness. On shores in west Scotland, *Chthamalus stellatus* and *Chthamalus montagui* are restricted to high shores as *Semibalanus balanoides*, the northern species, is competitively superior at these latitudes (Connell, 1961a,b). Further south in the UK, the two genera coexist in the mid-shore (Crisp *et al.*, 1981). Increased emergence would reduce the feeding time for attached suspension feeders within the biotope and the increased desiccation. It is likely that the distribution of *Chthamalus stellatus* will move further up the shore, with no noticeable difference in the range. *Chthamalus stellatus* / *Chthamalus montagui* are very tolerant of high periods of emersion, yet Patel & Crisp (1960) found that when barnacles which were brooding eggs were kept out of the water, a second batch of eggs was not produced. Decreased emergence is likely to lead to the habitat the biotope is found in becoming more suitable for the lower shore species generally found below the biotope, leading to replacement. Adults of *Chthamalus stellatus* can survive permanent submersion (Barnes, 1953). However, competition between *Semibalanus balanoides* is likely to play an important role in the changes in species distribution. *Semibalanus balanoides* is less tolerant of desiccation stress than *Chthamalus* barnacles species but is considered to out-compete *Chthamalus* spp. in the mid and lower shore.

Sensitivity assessment. Water relations (Fletcher 1980) are vital to the zonation of marine lichens and the 'black lichen belt' exists in a distinct balance between immersion and emersion. A decrease in emersion (increased inundation) would probably allow the 'black lichen belt' to extend up the shore (where suitable substratum exists) and replace supralittoral lichens at the bottom of the supralittoral. However, the lower littoral fringe would probably be lost to competition from macroalgae or barnacles, depending on the exposure of the shore, and the abundance of the characteristic barnacles would probably increase. Conversely, an increase in emersion (reduced inundation) would probably result in loss of the upper limit of the *Verrucaria maura* belt and its replacement by supralittoral lichens typical of the yellow-orange belt (e.g. *Caloplaca* spp.). Therefore, a decrease in emersion is likely to result in 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
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LR.FLR.Lic.Ver and Ver.Ver are recorded from very wave exposed to very wave sheltered conditions while Ver.B is only recorded from wave exposed conditions (Connor *et al.*, 2004). The 'black lichen band' tends to be wider in more wave exposed conditions, as the influence of wave action and splash are carried further up the shore. Therefore, changes in wave exposure may either increase or decrease the width of the 'black lichen band' depending on the nature of the shore. The extent of the band (especially Ver.B.) may extend on sheltered shore exposed to increased wave action but be reduced on wave exposed shores where the wave action is reduced, which suggests a **Low** resistance to change. Ver.B may be particularly sensitive to reduced wave exposure as it is only recorded from wave exposed shores. However, a change in significant wave height of 3-5% (the benchmark) is probably not significant on wave exposed shores, and might only be of minor benefit in the long-term on very sheltered shores. Therefore, a resistance of **High** is recorded, so that, a resilience of **High** and sensitivity of **Not sensitive** are recorded at the benchmark level.

Chemical Pressures

	Resistance	Resilience	Sensitivity
Transition elements & organo-metal contamination	High Q: Medium A: Medium C: Medium	High Q: High A: High C: High	Not sensitive Q: Medium 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 (Pb) to 100 ppm and cadmium (Cd) 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 littoral lichen 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
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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) recorded an oily film on the surface of *Verrucaria maura* but no apparent damage after the oil spill in Bantry Bay.
- 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).

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 littoral fringe 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, the 'black lichen belt' characterized by Ver.Ver and Ver.B are 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 '**Not relevant**' is recorded.

Nutrient 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

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. However, no evidence on the effects on *Verrucaria maura* was found. Holt *et al.* (1995) suggested that smothering of barnacles by ephemeral green algae is a possibility under eutrophic conditions.

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

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 was only significant in wave exposed sites where the cover of *Prasiola meridionalis* increased. Guano provides nitrates, phosphates, potassium and some salts (Wootton, 1991) but may introduce some organic material. In addition, organic-rich runoff, e.g. from agriculture and livestock, could introduce organic carbon to the littoral fringe. Organic-rich runoff would probably result in *Prasiola* growth over the 'black lichen belt', where wave exposure allowed. However, no direct evidence on the effects of organic enrichment in the littoral fringe was found and not sensitivity assessment was made.

A Physical Pressures

Resistance

None

Q: High A: High C: High

Resilience

Very Low

Q: High A: High C: High

Sensitivity

High

Q: High A: High C: High

Physical loss (to land or freshwater habitat)

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 community typical of this biotope is only found on hard substrata and dominates rocks in the littoral fringe. 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: Medium A: Medium C: Medium

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. However, no information on *Verrucaria maura* was found. *Verucaria maura* was not killed by high pressure washing during the *Sea Empress* oil spill cleanup (Moore, 2006) but 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.

The effects of trampling on barnacles appear to be variable with some studies not detecting significant differences between trampled and controlled areas (Tyler-Walters & Arnold, 2008). However, this variability may be related to differences in trampling intensities and abundance of populations studied. The worst case incidence was reported by Brosnan & Crumrine (1994) who reported that a trampling pressure of 250 steps in a 20x20 cm plot one day a month for a period of a year significantly reduced barnacle cover at two study sites. Barnacle cover reduced from 66% to 7% cover in 4 months at one site and from 21% to 5% within 6 months at the second site. Overall barnacles were crushed and removed by trampling. Barnacle cover remained low until recruitment the following spring. Long *et al.* (2011) also found that heavy trampling (70 humans km⁻¹ shoreline h⁻¹) led to reductions in barnacle cover. Single step experiments provide a clearer, quantitative indication of sensitivity to direct abrasion. Povey & Keough (1991) in experiments on shores in Mornington Peninsula, Victoria, Australia, found that in single step experiments 10 out of 67 barnacles, (*Chthamalus antennatus* about 3mm long), were crushed. However, on the same shore, the authors found that limpets may be relatively more resistant to abrasion from trampling. Following step and kicking experiments, few individuals of the limpet *Cellana trasomerica*, (similar size to *Patella vulgata*) suffered damage or relocated (Povey & Keough, 1991). One kicked limpet (out of 80) was broken and 2 (out of 80) limpets that were stepped on could not be relocated the following day (Povey & Keough, 1991). Trampling may lead to indirect effects on limpet populations, Bertocci *et al.* (2011) found that the effects of trampling on *Patella* sp. increased the temporal and spatial variability of in abundance. The experimental plots were sited on a wave-sheltered shore dominated by *Ascophyllum nodosum*. On these types of shore, trampling in small patches, that removes macroalgae and turfs, will indirectly enhance habitat suitability for limpets by creating patches of exposed rock for grazing.

Shanks & Wright (1986) found that even small pebbles (<6 cm) that were thrown by wave action in Southern California shores could create patches in *Chthamalus fissus* aggregations and could smash

owl limpets (*Lottia gigantea*). Average, estimated survivorship of limpets at a wave exposed site, with many loose cobbles and pebbles allowing greater levels of abrasion was 40% lower than at a sheltered site. Severe storms were observed to lead to the almost total destruction of local populations of limpets through abrasion by large rocks and boulders.

Sensitivity assessment. There is little direct evidence on the effect of surface abrasion on the 'black lichen belt'. *Verrucaria maura* is crustose and closely adherent to the rock surface so may resist abrasion and only be removed where the abrasion destroys the rock surface. However, the observation that fast growing lichen species come to dominate areas subject to disturbance (Fletcher, 1980) suggests that the 'black lichen belt' 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 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)

Medium

Q: Low A: NR C: NR

Medium

Q: Medium A: Medium C: Medium

Medium

Q: Low A: Low C: Low

The littoral fringe is rarely submerged 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, the 'black lichen belt' characterized by Ver.Ver and Ver.B are exposed to the air for the majority of the time. Hence, an increase in turbidity may not adversely affect the availability of light. Nevertheless, Fletcher (1980) noted that littoral fringe lichens die back in estuarine conditions but that loss of littoral lichens in estuaries can also be attributed to changes in salinity, pH, silt, reduced tidal range, or reduced wave exposure. Therefore, an increase in turbidity due to suspended solids (at the benchmark) may be detrimental to the characteristic *Verrucaria maura* and a resistance of '**Medium**' is suggested but at Low confidence. As resilience is probably '**Medium**', sensitivity is assessed as '**Medium**' at the benchmark level.

Smothering and siltation rate changes (light)

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 on the effect of siltation or smothering by sediment on littoral lichens was found. The lack of littoral lichens in estuaries was attributed to siltation amongst other factors by Fletcher (1980) but not to smothering alone. The barnacles that characterize this biotope are found permanently attached to hard substrata and are suspension feeders. They have no ability to escape from silty sediments that would bury individuals and prevent feeding and respiration. However, no direct evidence for sensitivity to siltation was found. Therefore, no sensitivity assessment was made.

Smothering and siltation rate changes (heavy)	No evidence (NEv)	Not relevant (NR)	No evidence (NEv)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

No evidence on the effect of siltation or smothering by sediment on littoral lichens was found. The lack of littoral lichens in estuaries was attributed to siltation amongst other factors by Fletcher (1980) but not to smothering alone. The barnacles that characterize this biotope are found permanently attached to hard substrata and are suspension feeders. They have no ability to escape from silty sediments that would bury individuals and prevent feeding and respiration. However, no direct evidence for sensitivity to siltation was found. Therefore, no sensitivity assessment was made.

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

Not assessed.

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

No evidence was found.

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

Not relevant

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

Verrucaria maura is well developed on both shaded and sunny coasts in Britain and Ireland but is considered a shade plant in North Africa, France and Scandinavia (Fletcher, 1980). *Verrucaria mucosa* and green forms of *Verrucaria striatula* increase in abundance on shaded shores and may, therefore, increase in abundance in the 'black lichen belt'.

Semibalanus balanoides sheltered from the sun grew bigger than unshaded individuals (Hatton, 1938; cited in Wetthey, 1984), although the effect may be due to indirect cooling effects rather than shading. Barnacles are also frequently found under algal canopies suggesting that they are tolerant of shading. Light levels have also been demonstrated to influence a number of phases of the reproductive cycle in *Semibalanus balanoides*. In general, light inhibits aspects of the breeding cycle. Penis development is inhibited by light (Barnes & Stone, 1972) while Tighe-Ford (1967) showed that constant light inhibited gonad maturation and fertilization. Davenport & Crisp (unpublished data from Menai Bridge, Wales, cited from Davenport *et al.*, 2005) found that experimental exposure to either constant darkness, or 6 h light: 18 h dark photoperiods induced autumn breeding in *Semibalanus*. They also confirmed that very low continuous light intensities (little more than starlight) inhibited breeding. Latitudinal variations in the timing of the onset of reproductive phases (egg mass hardening) have been linked to the length of darkness (night) experienced by individuals rather than temperature (Davenport *et al.*, 2005). Changes in light

levels associated with climate change (increased cloud cover) were considered to have the potential to alter the timing of reproduction (Davenport *et al.*, 2005) and to shift the range limits of this species southward.

However, it is not clear how these findings may reflect changes in light levels from artificial sources, and whether observable changes would occur at the barnacle population as a result. The artificial increase in light or shade may not adversely affect the littoral fringe, although seasonal opportunistic algae may be excluded and complete shade (darkness) may exclude even the lichens in the long-term. Therefore, resistance is probably '**High**' albeit with 'Low' confidence, so that resilience is '**High**' and the biotope is probably '**Not sensitive**' at the benchmark level.

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 the littoral fringe 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, and the visual acuity of barnacles is probably limited to detecting shading by predators, so the pressure is **Not relevant**.

Biological Pressures

Resistance

Resilience

Sensitivity

Genetic modification & translocation of indigenous species

No evidence (NEv)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

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

Introduction or spread of invasive non-indigenous species

No evidence (NEv)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

Essl & Lambdon (2009) reported that that only five 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.

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

Sensitivity assessment. Overall, there is little evidence of this biotope being adversely affected by non-native barnacle species and limited evidence on the effect of non-native lichens. Therefore, there is currently not enough evidence on which to base an assessment.

Introduction of microbial pathogens

High

Q: Low A: NR C: NR

High

Q: High A: High C: High

Not sensitive

Q: Low A: Low C: Low

No evidence on disease or pathogens mediated mortality in lichens was found. The characterizing barnacles and the limpet *Patella vulgata* are considered subject to persistent, low levels of infection by pathogens and parasites. For example, *Patella vulgata* has been reported to be infected by the protozoan *Urceolaria patellae* (Brouardel, 1948) at sites sheltered from extreme wave action in Orkney. Baxter (1984) found shells to be infested with two boring organisms, the polychaete *Polydora ciliata* and a siliceous sponge *Cliona celata*.

Sensitivity assessment. Based on the characterizing species and the lack of evidence for widespread, high-level mortality due to microbial pathogens the biotope is considered to have 'High' resistance to this pressure and therefore 'High' resilience (by default), the biotope is therefore considered to be 'Not sensitive'.

Removal of target species

No evidence (NEv)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

No information concerning the use of marine lichens was found. Extraction of lichens will undoubtedly reduce their abundance but probably not the extent of the supralittoral zone. However, **No evidence** of targeted removal was found. Similarly, barnacles are not subject to targeted removal.

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, thin and closely attached to the surface of hard rocks. Similarly, barnacles are closely adherent to the rock surface. It is 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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