Faunal crusts on wave-surged littoral cave walls

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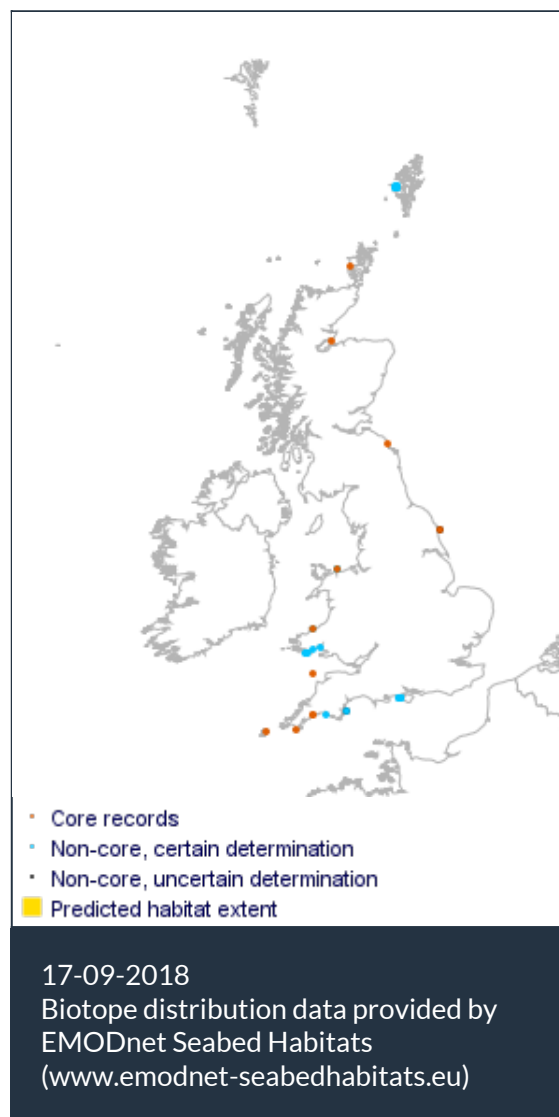
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Faunal crusts on wave-surged littoral cave walls
Photographer: Eleanor Murray
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- Core records
- Non-core, certain determination
- Non-core, uncertain determination
- Predicted habitat extent

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

Researched by	John Readman, Dr Heidi Tillin & Charltotte Marshall	Refereed by	This information is not refereed.

Summary

☰ UK and Ireland classification

EUNIS 2008	A1.448	Faunal crusts on wave-surged littoral cave walls
JNCC 2015	LR.FLR.CvOv.FaCr	Faunal crusts on wave-surged littoral cave walls
JNCC 2004	LR.FLR.CvOv.FaCr	Faunal crusts on wave-surged littoral cave walls
1997 Biotope		

🏷 Description

The inner walls of caves, predominantly in the mid shore in wave-surged conditions dominated by barnacles *Semibalanus balanoides* and *Verruca stroemia* with patches of encrusting sponges such as *Halichondria panicea* and *Grantia compressa* and occasional patches of the mussel *Mytilus edulis*. Increased moisture allows a denser faunal population than ScrFa to develop within the cave. The limpet *Patella vulgata* and spirorbid tube-forming polychaetes can be present. The

hydroid *Dynamena pumila* and anemones such as *Metridium dianthus* and *Actinia equina* may occur towards the lower reaches of the cave. Where a dense faunal turf of barnacles or bryozoan crusts covers the cave walls, the biotope can also extend to cover the ceiling and may be accompanied by the bryozoan *Alcyonidium diaphanum*. Variations of this biotope may occur in mid and lower shore scoured caves in south Wales the rock is dominated by dense *Sabellaria alveolata*. In south-west England the rock can be completely covered by the barnacle *Balanus perforatus*. There may be a variation in the species composition from cave to cave, depending on local conditions.This biotope usually occurs above the sand/pebble scoured ScrFa zone and may extend to the ceilings of the caves. (Information from Connor *et al.*, 2004; JNCC, 2015).

↓ Depth range

Mid shore, Lower shore

🏛 Additional information

-

✔ Listed By

- none -

✎ Further information sources

Search on:

G g G JNCC

Habitat review

⟳ Ecology

Ecological and functional relationships

This biotope is dominated by species able to withstand the frequent disturbance caused by wave surges. This in itself means that the community is unlikely to be a climax community, but more a transient community dominated by ephemeral, rapidly growing species that are able quickly to dominate spaces created by wave energy. Furthermore, the fauna is likely to vary both spatially, i.e. between caves, and on a temporal basis, depending on the frequency, severity and timing of disturbance. Competition for space may be high where disturbance is less frequent or less severe, for example, on or near the cave floor (if the floor is permanently submerged). Both the flora and fauna are dominated by low lying encrusting forms. The lack of erect and massive species reflects the high energy wave environment. On a sublittoral, vertical rock wall in Maine, Sebens (1985) listed the most rapid colonizers of bare rock to include spirorbid worms, encrusting bryozoans, red crustose algae, and erect hydroids and bryozoans. The assemblage mentioned in Sebens' study is very similar to the community that characterizes this biotope.

- Erect algae are invariably absent in this biotope because they would probably not survive the persistent wave surges. The primary producers, therefore, are mostly represented by encrusting coralline algae, e.g. *Lithophyllum incrustans*
- Suspension feeders are the dominant trophic group although the dominant species is likely to vary between caves and in different geographic areas.
- Active suspension feeders that feed on bacteria, phytoplankton and organic particulates and detritus include sponges, encrusting bryozoans, occasional erect bryozoans and barnacles. The barnacles *Semibalanus balanoides* and *Verruca stroemia* may be abundant, although in the south-west of England, it is the barnacle *Perforatus perforatus* which may completely cover the cave walls. *Semibalanus balanoides* suspension feeds both passively and actively, depending on current flow. Patches of encrusting sponge, especially the breadcrumb sponge *Halichondria panicea* and *Grantia compressa* may be found in damper areas of the cave. Damp crevices may give rise to small patches of the common mussel *Mytilus edulis* and anemones (see below). Encrusting bryozoans may form large turf areas and may include species such as *Cryptosula pallasiana* and *Haplopoma graniferum*. Erect bryozoans may be present in the upper reaches of the cave, where the effects of wave surge are reduced, or possibly submerged at the bottom of the cave and might include *Alcyonidium diaphanum* and *Crisularia plumosa*, the latter known to be found hanging in caves (Ryland & Hayward, 1977). Other active filter feeders likely to be present are tubeworms, such as *Spirobranchus triqueter* which is an opportunistic species rapidly able to colonize space.
- Passive suspension feeders feed on organic particulates, plankton and other small animals, and may include hydroids such as *Dynamena pumila* and anemones including the plumose anemone *Metridium dianthus* and the beadlet anemone *Actinia equina*. These anemones can feed on larger prey items and may also be present in the lower and submerged reaches of the cave, providing sand scour is not a significant factor.

- When the floor of the cave if submerged, mobile fish predators may prey upon on the smaller invertebrates. Blennies, for example, will feed on the barnacles.
- The combination of the wave-surged habitat and the lack of easily digestible plant material mean that grazers are uncommon, although the common limpet *Patella vulgata*

may be found occasionally as it is capable of feeding on the encrusting red algae.

Competition

Where a dense faunal crust covers the cave walls, space may become a limiting factor and some competition may occur. The anemones *Metridium senile* and *Actinia equina* are unlikely to be grown over (Sebens, 1985). Furthermore, both anemones can sting other anemones (Purcell, 1977; Manuel, 1988) and may therefore be competitively superior to other anemones where space is limited. The breadcrumb sponge *Halichondria panicea* was reportedly overgrown by everything apart from bryozoans in Sebens' (1985) study. This may explain why this sponge, and others, are usually only found in small patches within this biotope. Erect forms such as hydroids and the erect bryozoan *Alcyonidium diaphanum* may escape the immediate effects of competition from encrusting forms by developing vertically rather than laterally (Seed *et al*., 1983).

Seasonal and longer term change

On wave exposed shores, it is usually the macroalgae that display the most obvious seasonal and temporal changes in abundance. In this biotope, however, it is the invertebrate species that demonstrate such cyclical changes. Some species of bryozoans and hydroids demonstrate seasonal cycles of growth in spring/summer and regression (die back) in late autumn/winter, overwintering as dormant stages or juvenile stages (see Ryland, 1976; Gili & Hughes, 1995; Hayward & Ryland, 1998). Many of the bryozoans and hydroid species are opportunists adapted to rapid growth and reproduction (r-selected), taking advantage of the spring/summer phytoplankton bloom and more favourable (less stormy) conditions (Dyrynda & Ryland, 1982; Gili & Hughes, 1995). Henry (2002) reported a drastic decline in *Dynamena pumila* over the winter months in the Bay of Fundy. The tubeworm *Spirobranchus triqueter* is also an opportunist that can quickly colonize bare rock. In a wave-surged biotope such as this, seasonal changes may be masked by the temporal changes brought about by wave disturbance. Furthermore, the timing of the large disturbances (in terms of time of year) will most likely influence the initial succession of the community. In addition, the community at any given time is likely to vary significantly in terms of abundant species between different caves. As a result of the continual disturbance resulting from wave surges, the community associated with this biotope can not be considered a 'climax' community *per se* and will continually undergo temporal changes.

Habitat structure and complexity

Cave habitats are extremely varied and can be complex in terms of morphology. The most simple cave form may be a cave that has a single entrance and that retreats some distance either into a chamber, tunnel or tapered end of some description. More importantly, there are no holes in the roof of the cave and, therefore, light gradually diminishes with depth into the cave. Invariably, however, cave morphology is not as simplified as this and all caves will vary in terms of, for example:

- the amount of light penetrating into them,
- the depth of the water on the cave floor,
- the height of the cave to the roof,
- the amount of freshwater (if any) entering the cave through seepage or through cracks and fissures etc,
- the length to which the waves penetrate the cave (short caves parallel to the current will obviously experience a greater surge than long caves perpendicular to the current) and
- the extent to which the waves are funneled into the cave, e.g. short and narrow caves will most likely experience a greater surge than deep spacious caves where the waves will be

dissipated over the large surface floor area.

The floor of the cave may be submerged at all times and the back of the cave will be damper than at the front. The walls of the cave are likely to have cracks and fissures along which moisture will collect. It is in such microhabitats that animals less adapted to desiccation will be found, for example, plumose anemones. The walls themselves may be vertical or overhanging and there may also be horizontal platforms on which water and sediment may settle. Due to the possibility of sediment settlement and puddles of water, such platforms may again give rise to a community comparably different to the rest of the cave, for example, *Sabellaria alveolata* crusts. The distribution of the flora and fauna within the cave will reflect their ability to withstand various stressors including desiccation, low light levels and sand scour.

Norton *et al.* (1971) studied the distribution of organisms in relation to light in a cave on Bullock Island, Lough Hyne, Ireland. They found that the level of light reaching the organisms was much greater when the cave walls were not entirely immersed. This was because when the cave is only partly immersed, the organisms receive both direct light and reflected light.

Productivity

No information was found concerning the productivity in this biotope but it is expected to be low. Encrusting algae are generally resistant to most grazers and as a consequence, will pass on little in terms of primary production to higher trophic levels. Only their spores and fragments of the algae may enter the food chain of local, subtidal ecosystems, or be exported further offshore. Rocky shores make a contribution to the food of many marine species through the production of planktonic larvae and propagules which contribute to pelagic food chains.

Recruitment processes

Apart from the encrusting algae, the majority of important 'other' species associated with this biotope produce planktonic larvae and have annual recruitment.

- *Semibalanus balanoides* produce one brood of between 5000 and 10000 eggs per year. The planktotrophic nauplii larvae develop in the surface waters for about two months although settlement and subsequent recruitment is highly variable.
- *Perforatus perforatus* releases nauplii into the plankton during the summer and the cyprids settle on the shore during early autumn (Fish & Fish, 1996).
- Sponges may proliferate both asexually and sexually. Most sponges are hermaphroditic but cross-fertilization normally occurs. The process may be oviparous, where there is a mass spawning of gametes through the osculum which enter a neighbouring individual in the inhalant current. Fertilized eggs are discharged into the sea where they develop into a planula larva. However, in the majority development is viviparous, whereby the larva develops within the sponge and is then released. Larvae have a short planktonic life of a few hours to a few weeks, so that dispersal is probably limited and asexual reproduction probably results in clusters of individuals.
- Many anthozoans reproduce both sexually and asexually. The beadlet anemone *Actinia equina* frequently reproduces by viviparity whereby internal fertilization is followed by the release of fully formed young (Manuel, 1988).
- Spawning in *Sabellaria alveolata* occurs each July but subsequent recruitment can vary considerably from year to year. The larvae spend between 6 weeks and 6 months in the plankton. This could enhance the potential for recruitment from external sources, although it is the presence of some remaining adults that will assist in larval settlement as

this is the preferred substratum (Wilson, 1929).

- Hayward & Ryland (1995b) and Segrove (1941) suggested that breeding of *Spirobranchus triqueter* probably takes place throughout the year although several authors have suggested that there is a peak in breeding in some areas (see *MarLIN* review). Larvae are pelagic for about 2-3 weeks in the summer although this increases to about two months in winter (Hayward & Ryland, 1995b). Settlement is thought to be minimal over the winter months.
- *Lithophyllum incrustans* reproduce annually and it has been calculated that 1 mm of reproductive thallus produces 17.5 million bispores per year with an average settlement of only 55 sporelings/year (Edyvean & Ford, 1984).
- Dispersal of the hydroid *Dynamena pumila* is restricted to the planula stage which usually settles and starts to metamorphose within 60 hours of release (Orlov, 1996). Seed *et al.* (1981) reported that the reproductive zooids of *Dynamena pumila* were in abundance between May and August in Strangford Lough, Northern Ireland.
- Little information was found concerning recruitment in the ctenostome bryozoan *Alcyonidium diaphanum*. However, Wood & Seed (1992) reported that in populations of *Alcyonidium hirsutum* and *Flustrellidra hispida* (two other common ctenostome bryozoans) in the Menai Strait, larval release occurred over a protracted period. Little growth was observed over the winter months and few survived to their second year. The brooded, lecithotrophic coronate larvae of many bryozoans have a short pelagic lifetime of several hours to about 12 hours (Ryland, 1976). Recruitment is dependant on the supply of suitable, stable, hard substrata (Eggleston, 1972b; Ryland, 1976; Dyrynda, 1994).

Time for community to reach maturity

Although no information was found concerning temporal changes in this biotope especially, work has been done on similar habitats. Sebens (1985, 1986), for example, studied the succession of a community on the vertical rock walls in the Gulf of Maine. Although the patterns of succession recorded in his work are not entirely relevant here (since his study followed a two year successional period which is unlikely in this biotope given that it is characterized by frequent disturbance), the patterns of recolonization he observed are relevant. This biotope is subjected to frequent small disturbances and the associated community is characterized by relatively short lived and opportunistic species. Furthermore, 'maturity' may well be hard to define for this biotope since the composition of the flora and fauna is likely to change quite dramatically between caves, depending on local environmental conditions. Nonetheless, it is likely that the time taken for the community to reach maturity will be no more than a few years. The spirorbids, encrusting bryozoans, red crustose algae, erect hydroids and bryozoans mentioned in Sebens study (1985) all covered the cleared areas within 1-4 months in the spring, summer and autumn months. The encrusting algae *Lithothamnion glaciale* took about 3 years to reappear (Sebens, 1985) and the breadcrumb sponge *Halichondria panicea* approached previous cover in about 2 years or more (Sebens, 1985).

Additional information

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🖼 Preferences & Distribution

Habitat preferences

Depth Range	Mid shore, Lower shore
Water clarity preferences	No information found
Limiting Nutrients	Data deficient, No information found
Salinity preferences	Full (30-40 psu)
Physiographic preferences	
Biological zone preferences	Eulittoral
Substratum/habitat preferences	Bedrock, Caves
Tidal strength preferences	No information
Wave exposure preferences	Exposed, Moderately exposed, Sheltered
Other preferences	Sheltered to exposed coasts.

Additional Information

This biotope is found on the vertical walls and ceilings of dark, damp caves. The caves must be damp in order to sustain the various soft bodied faunal and floral crusts.

🐾 Species composition

Species found especially in this biotope

Rare or scarce species associated with this biotope

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Additional information

A full species list was unavailable for this biotope. However, given the extreme habitat with which it is associated, species diversity is likely to be quite low with a noticeable absence of erect algal species.

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

This biotope is characterized by a faunal assemblage that typically includes barnacles such as *Semibalanus balanoides* or *Verrucosa stroemia* with patches of encrusting sponges such as *Halichondria panicea.*

The biotope tends to occur above the sand/pebble scoured LR.FLR.CvOv.ScrFa in wave surged caves in which the moisture allows a denser faunal population to develop. The biotope varies considerably in composition (Connor *et al.*, 2004) and the sensitivity assessments focus on the barnacle and sponge components as they are considered the important defining species. Other species associated with this biotope, such as limpets, mussels, anemones and hydroids, may not always be present and are, therefore, not considered to be 'important characterizing'.

Resilience and recovery rates of habitat

The species that characterize this biotope are generally robust animals that can withstand some physical disturbance and/or recover rapidly. This biotope is therefore considered to have a high recovery potential. Sponges and anemones can repair damage and regenerate from small, surviving body parts. Other species such as limpets and isopods are mobile and can migrate into the biotope as adults, while other attached species such as the barnacles and spirorbids produce large numbers of pelagic larvae that can recolonize suitable habitats. Most of the epifauna is probably subject to severe physical disturbance and scour during winter storms and probably develops annually, through regrowth, recolonization and migration from adjacent habitats. Therefore, recovery is likely to be rapid as a typical biological assemblage develops within less than year and probably within 6 months in spring and summer.

Little information on sponge longevity and resilience exists. Reproduction can be asexual (e.g. budding) or sexual (Naylor, 2011) and individual sponges are usually hermaphrodites (Hayward & Ryland, 1994). Short-lived ciliated larvae are released via the aquiferous system of the sponges and metamorphosis follows settlement. Growth and reproduction are generally seasonal (Hayward & Ryland, 1994). Rejuvenation from fragments is also considered an important form of reproduction (Fish & Fish, 1996). Some sponges are known to be highly resilience to physical damage with an ability to survive severe damage, regenerate and reorganize to function fully again. However, this recoverability varies between species (Wulff, 2006). Many sponges recruit annually and growth can be rapid, with a lifespan of one to several years (Ackers, 1983). However sponge longevity and growth has been described as highly variable depending on the species and environmental conditions (Lancaster *et al.*, 2014). It is likely that erect sponges are generally longer lived and slower growing given their more complex nature than smaller encrusting or cushion sponges. Fowler & Laffoley (1993) monitored the marine nature reserves in Lundy and the Isles Scilly and found that a number of common sponges showed great variation in size and cover during the study period. Large colonies appeared and vanished at some locations. Some large encrusting sponges went through periods of both growth and shrinkage, with considerable changes taking place from year to year. For example, *Cliona celata* colonies generally grew extremely rapidly, doubling their size or more each year, but in some years an apparent shrinkage in size also took place. In contrast, there were no obvious changes in the cover of certain unidentified thin encrusting sponges.

Hymeniacidon perleve is found in thin sheets, cushions and rarely as erect and branching. It is found

from the Arctic to the Mediterranean from the littoral to the circalittoral (Ackers *et al.*, 1992). *Halichondria panicea* is very polymorphic, varying from thin sheets, massive forms and cushions to branching. It crumbles readily and branches are brittle (breaking if bent through 20°).   An opportunistic species, it is found in wide range of niches on rock or any other hard substratum (Ackers *et al.*, 1992). Barthel (1986) reported that *Halichondria panicea* in the Kiel Bight went through annual cycles, with growth occurring between March and July. After July, a strong decline in mean individual weight occurred until the end of September. No change in individual weight was observed over winter, although a change in biochemical composition (condition index and protein, lipid and glycogen content) was noted. Reproductive activity occurred in August and September with young colonies appearing in early autumn. Adult *Halichondria panicea* degenerated and disintegrated after reproduction. Fish & Fish (1996), however, suggested a lifespan of about three years and Vethaak *et al.* (1982) reported that *Halichondria panicea* survived the winter in a normal, active state in the Oosterschelde.   Fell & Lewandrowski (1981) observed the population dynamics of *Halichondria* spp. within an eelgrass bed in an estuary in Connecticut, US over a two year period. Large numbers of larval derived specimens developed on the eelgrass during the summer, and many of these sponges became sexually reproductive, further increasing the size of the population. However, mortality was high, and at the end of the summer, only a relatively small sponge population remained. Sexual reproduction by larva-derived specimens of *Halichondria* spp. occurred primarily after breeding by the parental generation had declined. The larva-derived sponges grew rapidly, and the percentage of specimens containing large, female reproductive elements increases with specimen size. *Halichondria* spp. exhibited an opportunistic life strategy with a 'high rate of turnover'. Thomassen & Riisgard (1995) described a number of studies looking at the growth rates of *Halichondria* spp. with rates of between 1% and 3.3% of total volume per day.   Sebens (1985; 1986) monitored recolonization of epifauna on cleared vertical rock walls and described the sponge *Halichondria panicea* as reaching pre-clearance levels of cover after 2 years.

On rocky shores, barnacles are often quick to colonize available gaps, although a range of factors, as outlined below, will influence whether there is a successful episode of recruitment in a year to re-populate a shore following impacts. 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, that had previously been dominated by *Ascophyllum nodosum* However, barnacle densities were fairly low (on average 7.6 % cover) as predation levels in smaller patches were high and heat stress in large areas may have killed a number of individuals (Petraitis *et al.*, 2003). Following the creation of a new shore in the Moray Firth, *Semibalanus balanoides* did not recruit in large numbers until 4 years after shore creation (Terry & Sell, 1986).

Successful recruitment of a high number of *Semibalanus balanoides* individuals to replenish the population may be episodic (Kendall *et al.*, 1985).   After settlement, the juveniles are subject to high levels of predation as well as dislodgement from waves and sand abrasion depending on the area of settlement. *Semibalanus balanoides* may live up to 4 years in higher areas of the shore (Wethey, 1985). Predation rates are variable (see Petraitis *et al.*, 2003) and are influenced by a number of factors including the presence of algae (that shelters predators such as the dog whelk, *Nucella lapillus*, and the shore crab, *Carcinus maenas* and the sizes of clearings (as predation pressure is higher near canopies (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 balanoide*s dying within ten days (Kendall *et al.*, 1985). Presumably, these factors also influence the transport, supply and settlement of *Chthamaus* spp., *Balanus crenatus* and other species such as spirorbids that produce pelagic larvae.

Resilience assessment

Whilst barnacles have been recorded as requiring up to three years to reach pre-clearance levels, the prevailing conditions in the biotope of wave surge and lack of algal species are likely to limit predation, and recovery is, therefore, likley to be more rapid. Overall, resilience is assessed as 'High' (within 2 years) for all levels of impact, even where resistance is none, as it is likely that a similar community can rapidly develop.

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

🚢 Hydrological Pressures

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

Examples of distribution and thermal tolerances tested in laboratory experiments are provided as evidence to support the sensitivity assessment. In general, populations can acclimate to prevailing conditions which can alter tolerance thresholds and care should, therefore, be used when interpreting reported tolerances. Species that are found in the intertidal are exposed to extremes of high and low air temperatures during periods of emersion. They also experience temperature fluctuation over a short period of time during the tidal cycle. In winter air temperatures are colder than the sea, conversely in summer air temperatures are much warmer than the sea. In general intertidal species are therefore able to tolerate a wide range of temperatures. Within this biotope, the cave habitat provides some shade and hence cooler temperatures and reduced desiccation supporting species typically found lower on the shore such as *Balanus crenatus* and encrusting corallines.

The barnacles *Semibalanus balanoides* and *Balanus crenatus* are both 'northern species'. *Semibalanus balanoides* extend from Portugal or Northern Spain to the Arctic circle. Populations in the southern part of England are therefore relatively close to the southern edge of their geographic range. *Semibalanus balanoides* are found on the mid-shore but are less resistant to desiccation that the 'southern' Chthamalus barnacle species. 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 $^{\circ}$C inhibit reproduction (Barnes, 1957, 1963, Crisp & Patel, 1969) and laboratory studies suggest that temperatures at or below 10 $^{\circ}$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 $^{\circ}$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).

Balanus crenatus is described as a boreal species (Newman & Ross, 1976) it is found throughout the northeast Atlantic from the Arctic to the west coast of France as far south as Bordeaux; east and west coasts of North America and Japan. In Queens Dock, Swansea where the water was on average 10°C higher than average due to the effects of a condenser effluent, *Balanus crenatus* was replaced by the subtropical barnacle *Balanus amphitrite*. After the water temperature cooled *Balanus crenatus* returned (Naylor, 1965). The increased water temperature in Queens Dock is greater than an increase at the pressure benchmark (2-5°C). *Balanus crenatus* has a peak rate of cirral beating at 20°C and all spontaneous activity ceases at about 25°C (Southward, 1955). The tolerance of *Balanus crenatus*, collected in the summer (and thus acclimated to higher temperatures), to increased temperatures was tested in the laboratory. The median upper lethal temperature tolerance was -25.2°C (Davenport & Davenport, 2005) confirming the observations of Southward (1955).

Increased temperatures are likely to favour Chthamalid barnacles present in the biotope rather than *Semibalanus balanoides* (Southward *et al*. 1995) and *Balanus crenatus*. *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. *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).

Berman *et al*. (2013) monitored sponge communities off Skomer Island, UK over three years with all characterizing sponges for this biotope assessed. Seawater temperature, turbidity, photosynthetically active radiation and wind speed were all recorded during the study. It was concluded that, despite changes in species composition, primarily driven by the non-characterizing *Hymeraphia*, *Stellifera* and *Halicnemia patera*, no significant difference in sponge density was recorded in all sites studied. Morphological changes most strongly correlated with a mixture of water visibility and temperature. Barthel (1986) reported that reproduction and growth in *Halichondria panicea* in the Kiel Bight were primarily driven by temperature, with higher temperatures corresponding with the highest growth.

Sensitivity assessment. Typical surface water temperatures around the UK coast vary, seasonally from 4-19°C (Huthnance, 2010). The biotope is considered to tolerate a 2°C increase in temperature for a year. An acute increase at the pressure benchmark may be tolerated in winter, but a sudden return to typical temperatures could lead to mortalities among acclimated animals. However, no evidence was found to support this assessment. An acute increase of 5°C in summer would be close to the lethal thermal temperature for *Balanus crenatus*. Adult *Semibalanus balanoides*

are considered likely to be able to tolerate an acute or chronic change, however, if an acute change in temperature occurred in autumn or winter it could disrupt reproduction, while a chronic change could alter reproductive success if it exceeded thermal thresholds for reproduction. The effects would depend on the magnitude, duration and footprint of the activities leading to this pressure. However, barnacle populations are highly connected, with a good larval supply and high dispersal potential (Wethey *et al.*, 2011, Rognstad *et al.*, 2014).   Resistance is therefore assessed as **'High'** (despite some potential effects on reproductive success) and resilience as **'High'** (by default). This biotope is therefore considered to be **'Not sensitive'** at the pressure benchmark, although some changes in the proportions of different barnacle species may occur.

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

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

The barnacle *Semibalanus balanoides* is primarily a 'northern' species with an arctic-boreal distribution. Long-term time series show that recruitment success is correlated to lower sea temperatures (Mieszkowska *et al.*, 2014). Due to warming temperatures its range has been contracting northwards. Temperatures above 10 to 12 $^{\circ}$C inhibit reproduction (Barnes, 1957, 1963, Crisp & Patel, 1969) and laboratory studies suggest that temperatures at or below 10 $^{\circ}$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). 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 $^{\circ}$C (Davenport & Davenport, 2005). A decrease in temperature at the pressure benchmark is, therefore, unlikely to negatively affect this species. *Balanus crenatus* is described as a boreal species (Newman & Ross, 1976) it is found throughout the northeast Atlantic from the Arctic to the west coast of France as far south as Bordeaux; east and west coasts of North America and Japan. *Chthamalus stellatus* and *Chthamalus montagui* are 'southern' barnacle species and their range has been extending northwards due to increasing temperatures. *Chthamalus* suffers a failure of fertilization at temperatures of 9 °C and below (Patel and 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 (Wethey et al., 2011).

The characterizing sponge *Halichondria panacea* is widely distributed across the coasts of the British Isles and is found from the Channel Isles to Northern Scotland (NBN, 2015). Berman *et al.* (2013) monitored sponge communities off Skomer Island, UK over three years. seawater temperature, turbidity, photosynthetically active radiation and wind speed were all recorded during the study. It was concluded that, despite changes in species composition, primarily driven by the non-characterizing *Hymeraphia Stellifera* and *Halicnemia patera*, no significant difference in sponge density was recorded in all sites studied. Morphological changes most strongly correlated with a mixture of visibility and temperature. Crisp (1964) studied the effects of an unusually cold winter (1962-3) on the marine life in Britain, including porifera in North Wales. Whilst difficulty in

distinguishing between mortality and delayed development was noted, Crisp found that *Halichondria panicea* was wholly or partly killed by frost. Barthel (1986) also reported that *Halichondria panicea* in the Kiel Bight degenerated and disintegrated after reproduction before winter, however, young colonies were observed from September and this could be the survival mechanism.

The limpet, *Patella vulgata* is largely unaffected by short periods of extreme cold. Ekaratne & Crisp (1984) found adult limpets continuing to grow over winter when temperatures fell to -6°C, and stopped only by still more severe weather. However, loss of adhesion after exposure to -13°C has been observed with limpets falling off rocks and therefore becoming easy prey to crabs or birds (Fretter & Graham, 1994). However, in the very cold winter of 1962-3 when temperatures repeatedly fell below 0°C over a period of 2 months large numbers of *Patella vulgata* were found dead (Crisp, 1964). Periods of frost may also kill juvenile *Patella vulgata*, resulting in recruitment failures in some years (Bowman & Lewis, 1977).

Sensitivity assessment. The majority of species considered have a wide temperature tolerance range and the acute and chronic decreases in temperature described by the benchmark would have limited effect on barnacles and limpets. However, there is evidence of mortality in sponges including *Halichondria panicea* at extreme low temperatures in the British Isles. Given this evidence, it is likely that a cooling of 5°C for a month could potentially affect the characterizing sponge, and resistance has, therefore, been assessed as '**Medium'**. Resilience is '**High'** and sensitivity is therefore as '**Low**' at the benchmark level.

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

This biotope is recorded in variable (18-35 ppt) to full salinity (30-35 ppt) habitats (Connor *et al*., 2004) and therefore the sensitivity assessment benchmark considers an increase from full salinity to >40 ppt. Biotopes found in the intertidal will naturally experience fluctuations in salinity where evaporation increases salinity and inputs of rainwater expose individuals to freshwater. Species found in the intertidal are therefore likely to have some form of behavioural or physiological adaptations to changes in salinity.

Barnes & Barnes (1974) found that larvae from six barnacle species including *Balanus crenatu*s, *Chthamalus stellatus* and S*emibalanus (as Balanus) balanoides*, completed their development to nauplii larvae at salinities between 20-40‰. (Some embryos exposed at later development stages could survive at higher and lower salinities). *Balanus crenatus* occurs in estuarine areas and is therefore adapted to variable salinity (Davenport, 1976). When subjected to sudden changes in salinity *Balanus crenatus* closes its opercular valves so that the blood is maintained temporarily at a constant osmotic concentration (Davenport, 1976). No evidence for *Halichondria panicea* in hypersaline conditions was found.

Sensitivity assessment. Little direct evidence was found to assess sensitivity to this pressure. Although some increases in salinity may be tolerated by the associated species present these are generally short-term and mitigated during tidal inundation. This biotope is considered, based on distribution on the mid-shore to be sensitive to a persistent increase in salinity to > 40 ppt. Resistance is therefore assessed as 'Low' and recovery as 'High' (following the restoration of usual salinity). Sensitivity is therefore assessed as 'Low'.

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

This biotope is recorded in variable (18-35 ppt) to full salinity (30-35 ppt) (Connor *et al.*, 2004). At the pressure benchmark, a change from variable to reduced salinity (18-30 ppt) is assessed.

Balanus crenatus occurs in estuarine areas and is therefore probably adapted to reduced salinity (Davenport, 1976). When subjected to sudden changes in salinity *Balanus crenatus* closes its opercular valves so that the blood is maintained temporarily at a constant osmotic concentration (Davenport, 1976). Acclimation to different salinity regimes alters the point at which opercular closure and resumption of activity occur (Davenport, 1976). *Balanus crenatus* can tolerate salinities down to 14 psu if given time to acclimate (Foster, 1970). At salinities below 6 psu, motor activity ceases, respiration falls and the animal falls into a "salt sleep". In this state the animals may survive (Barnes & Barnes, 1974) in freshwater for 3 weeks, enabling them to withstand changes in salinity over moderately long periods (Barnes & Powell, 1953). Larvae are more sensitive than adults. In culture experiments, eggs maintained below 10‰ rupture, due to osmotic stress (Barnes & Barnes, 1974). At 15-17‰ there is either no development of early stages or the nauplii larvae are deformed and "probably not viable", similarly at 20‰ development occurs, but about half of the larvae are deformed and not viable. (Barnes & Barnes, 1974). Normal development resulting in viable larvae occurs between salinities of 25-40 ‰ (Barnes & Barnes, 1974). 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, 1971). *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).

Halichondria panicea has been recorded in reduced salinity biotopes, such as SIR.ESTFA.MytT (Connor *et al.*, 2004) and occurs in outer and mid estuaries (Hayward & Ryland 1995b).

Sensitivity assessment. All characterizing species are found in salinities of 18 ppt or lower and are therefore unlikely to be affected at the benchmark level. The biotope is considered 'Not sensitive' to a decrease in salinity from variable to reduced. Biotope resistance is therefore assessed as **'High'** and resilience is assessed as **'High'** (by default) and the biotope is assessed as **'Not sensitive'** at the benchmark level.

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

The barnacles and encrusting sponges characterizing this biotope are securely attached and as these are relatively flat and small they are subject to little or no drag compared to upright growth forms.

Changes in flow rate may impact the supply of food to filter feeders. Laboratory experiments demonstrate that barnacle feeding behaviour alters over different flow rates but that barnacles can feed at a variety of flow speeds (Sanford *et al.*, 1994). Flow tank experiments using velocities of 0.03, 0.07 and 0.2 m/s showed that a higher proportion of barnacles fed at higher flow rates

(Sanford *et al.*, 1994). Feeding was passive, meaning the cirri were held out to the flow to catch particles; although active beating of the cirri to generate feeding currents occurs in still water (Crisp & Southward, 1961). Field observations at sites in southern New England (USA) that experience a number of different measured flow speeds, found that *Semibalanus balanoides* from all sites responded quickly to higher flow speeds, with a higher proportion of individuals feeding when current speeds were higher. Barnacles were present at a range of sites, varying from sheltered sites with lower flow rates (maximum observed flow rates <0.06- 0.1 m/s), a bay site with higher flow rates (maximum observed flows 0.2-0.3 m/s) and open coast sites (maximum observed flows 0.2-0.4 m/s). Recruitment was higher at the site with flow rates of 0.2-0.3 m/s (although this may be influenced by supply) and at higher flow microhabitats within all sites. Both laboratory and field observations indicate that flow is an important factor with effects on feeding, growth and recruitment in *Semibalanus balanoides* (Sanford *et al.*, 1994, Leonard *et al.*, 1998), however, the results suggest that flow is not a limiting factor determining the overall distribution of barnacles as they can adapt to a variety of flow speeds.

Riisgård *et al.* (1993) discussed the low energy cost of filtration for sponges and concluded that passive current-induced filtration may be insignificant for sponges. Pumping and filtering occurs in choanocyte cells that generate water currents in sponges using flagella (De Vos *et al.*, 1991). *Halichondria panicea* has been recorded in very strong to negligible biotope (0- > 3 m/sec).

Sensitivity assessment. The species that characterize or are associated with this biotope are securely attached and can occur in a range of flow speeds. The resistance of the biotope to changes in water flow is assessed as 'High' and resilience as 'High' (by default) so that the biotope is assessed as 'Not sensitive'. Scour is a key factor structuring this biotope (Connor *et al.*, 2004), changes in flow exceeding the pressure benchmark may increase or decrease sediment transport and associated scour may lead to indirect changes in the character of the biotope.

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

Emergence regime is a key factor structuring this (and other) intertidal biotopes. Increased emergence may reduce habitat suitability for characterizing species through greater exposure to desiccation and reduced feeding opportunities for the barnacles and other filter feeders including spirorbids, barnacles,sponges and anemones which feed when immersed. *Semibalanus balanoides* is less tolerant of desiccation stress than *Chthamalus* barnacles species and changes in emergence may, therefore, lead to species replacement and the development of a *Chthamalus* sp. dominated biotope, more typical of the upper shore may develop. It should be noted that moisture from wave surge is considered important in maintaining faunal abundance (Connor *et al.*, 2004*)*. Changes in emergence may therefore eventually lead to the replacement of this biotope to one more tolerant of desiccation.

Decreased emergence would reduce desiccation stress and allow the attached suspension feeders more feeding time. Predation pressure on barnacles and limpets is likely to increase where these are submerged for longer periods and to prevent colonisation of lower zones. *Semibalanus balanoides* was able to extend its range into lower zones when protected from predation by the dogwhelk, *Nucella lapillus* (Connell, 1961). Mobile species present within the biotope would be able to relocate to preferred shore levels. Where decreased emergence leads to increased abrasion and scour while immersed, the removal of fauna may lead to this biotope reverting to the more barren LR.FLR.CvOv.ScrFa.

Sensitivity assessment. As emergence is a key factor structuring the distribution of animals on the shore, resistance to a change in emergence (increase or decrease) is assessed as **'Low'**. Recovery is assessed as **'High'**, and sensitivity is therefore assessed as **'Low'**.

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

This biotope is recorded from locations that are judged to range from exposed to sheltered (Connor *et al.*, 2004). The barnacles and encrusting sponges associated with this biotope have a flat growth form and are unlikely to be dislodged by increased wave action.

Sensitivity assessment. The biotope and characterizing and associated species are found across a range of wave exposures, populations occurring within the middle of the range are considered to have 'High' resistance to a change in significant wave height at the pressure benchmark. It should be noted that the biotope relies on wave surge to provide enough moisture to maintain an abundant fauna, a significant decrease could result in loss of the biotope to one more tolerant of desiccation. However, at the benchmark level, resistance is **'High'**. Resilience is assessed as **'High'**, by default, and the biotope is considered **'Not sensitive'**.

⚗ Chemical Pressures

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

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

No information was found concerning the effects of heavy metals on encrusting coralline algae. Bryan (1984) suggested that the general order for heavy metal toxicity in seaweeds is: organic Hg> inorganic Hg > Cu > Ag > Zn> Cd> Pb. Contamination at levels greater than the pressure benchmark may adversely impact the biotope. Cole *et al.* (1999) reported that Hg was very toxic to macrophytes. The sublethal effects of Hg (organic and inorganic) on the sporelings of *Plumaria elegans*, were reported by Boney (1971). 100% growth inhibition was caused by 1 ppm Hg.

Contamination at levels greater than the pressure benchmark may adversely impact the biotope. Barnacles accumulate heavy metals and store them as insoluble granules (Rainbow, 1987). Pyefinch & Mott (1948) recorded a median lethal concentration of 0.19 mg/l copper and 1.35 mg/l mercury, for *Balanus crenatus* over 24 hours. Barnacles may tolerate a fairly high level of heavy metals in nature, for example, they are found in Dulas Bay, Anglesey; where copper reaches concentrations of 24.5 μg/l, due to acid mine waste (Foster *et al.*, 1978).

While some sponges, such as *Cliona* spp. have been used to monitor heavy metals by looking at the associated bacterial community (Marques *et al.*, 2007; Bauvais *et al.*, 2015), no literature on the effects of transition element or organo-metal pollutants on the characterizing sponges could be found.

Bryan (1984) suggested that gastropods are also rather tolerant of heavy metals. In the Fal estuary *Patella vulgata* occurs at, or just outside, Restronguet Point at the end of the creek where metal

concentrations are in the order: Zinc (Zn) 100-2000µg/l, copper (Cu) 10-100 µg/l and cadmium (Cd) 0.25-5 µg/l (Bryan & Gibbs, 1983). However, in the laboratory *Patella vulgata* was found to be intolerant of small changes in environmental concentrations of Cd and Zn by Davies (1992). At concentrations of 10 µg/l pedal mucus production and levels of activity were both reduced, indicating a physiological response to metal concentrations. Exposure to Cu at a concentration of 100 µg/l for one week resulted in progressive brachycardia (slowing of the heart beat) and the death of limpets. Zn at a concentration of 5500 µg/l produced the same effect (Marchan *et al.*,1999).

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

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

Tethya lyncurium concentrated BaP (benzo[a]pyrene)to 40 times the external concentration and no significant repair of DNA was observed in the sponges, which, in higher animals, would likely lead to cancers. As sponge cells are not organized into organs the long-term effects are uncertain (Zahn *et al.*, 1981). No information was found on the intolerance of the characterizing sponges or barnacles to hydrocarbons. However, other littoral barnacles generally have a high tolerance to oil (Holt *et al.*, 1995) and were little impacted by the *Torrey Canyon* oil spill (Smith, 1968).

Synthetic compound contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

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

Barnacles have a low resilience to chemicals such as dispersants, dependant on the concentration and type of chemical involved (Holt *et al.*, 1995). They are less intolerant than some species (e.g. *Patella vulgata*) to dispersants (Southward & Southward, 1978) and *Balanus crenatus* was the dominant species on pier pilings at a site subject to urban sewage pollution (Jakola & Gulliksen, 1987). Hoare & Hiscock (1974) found that *Balanus crenatus* survived near to an acidified halogenated effluent discharge where many other species were killed, suggesting a high tolerance to chemical contamination. Little information is available on the impact of endocrine disrupters on adult barnacles. Holt *et al.* (1995) concluded that barnacles are fairly sensitive to chemical pollution, therefore intolerance is reported as high. The species is an important early colonizer of sublittoral rock surfaces (Kitching, 1937) and it heavily recolonized a site that was dredged for gravel within 7 months (Kenny & Rees, 1994). Therefore, recovery is predicted to be high.

Hoare & Hiscock (1974) reported that the limpet *Patella vulgata* was excluded from sites within 100-150m of the discharge of acidified, halogenated effluent in Amlwch Bay. Limpets are also extremely intolerant of aromatic solvent based dispersants used in oil spill clean-up. During the clean-up response to the *Torrey Canyon* oil spill, nearly all the limpets were killed in areas close to dispersant spraying. Viscous oil will not be readily drawn in under the edge of the shell by ciliary currents in the mantle cavity, whereas detergent, alone or diluted in seawater, would creep in much more readily and be liable to kill the limpet (Smith, 1968). A concentration of 5ppm killed half the limpets tested in 24 hours (Southward & Southward, 1978; Hawkins & Southward, 1992). Acidified seawater affects the motility of *Patella vulgata*. At a pH of 5.5 motility was reduced whilst submerged but individuals recovered when returned to normal seawater. At a pH of 2.5 total inhibition of movement occurred and when returned to normal seawater half had died (Bonner *et*

al., 1993). Reduced motility reduces the time for foraging and may result in decreased survival of individuals. Acidified seawater can also change the shell composition which will lead to a decrease in its protective nature and hence survival (Bonner *et al*., 1993). Short periods (48 hours) are unlikely to have much effect on a population but long periods (1 year) may cause reduced grazing and an increase in algal growth. However, seawater is unlikely to reach pH 2.5, therefore, intolerance to slight changes in pH will be low. Hoare & Hiscock (1974) reported that in Amlwch Bay *Patella vulgata* was excluded from sites within 100-150 m of the discharge of acidified, halogenated effluent.

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

Radionuclide contamination	No evidence (NEv)	No evidence (NEv)	No evidence (NEv)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

'No evidence'.

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

This pressure is **Not assessed**.

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

Specific information concerning oxygen consumption and reduced oxygen tolerances were not found for the important characterizing species within the biotope. It is likely that as this biotope occurs in areas that are shallow and tidally flushed that re-oxygenation is likely, limiting the effects of any de-oxygenation events. However, this may mean that the species present have little exposure to low oxygen and may be sensitive to this pressure. *Balanus crenatus*, however, respires anaerobically so it can withstand some decrease in oxygen levels. When placed in wet nitrogen, where oxygen stress is maximal and desiccation stress is minimal, *Balanus crenatus* has a mean survival time of 3.2 days (Barnes *et al*., 1963) and this species is considered to be 'Not sensitive' to this pressure. *Semibalanus balanoides* can respire anaerobically, so they can tolerate some reduction in oxygen concentration (Newell, 1979). When placed in wet nitrogen, where oxygen stress is maximal and desiccation stress is low, *Semibalanus balanoides* have a mean survival time of 5 days (Barnes *et al*., 1963).

In laboratory experiments, a reduction in the oxygen tension of seawater from 148mm Hg (air saturated seawater) to 50 mmHg rapidly resulted in reduced heart rate in limpets of the genus *Patella* (Marshall & McQuaid, 1993). Heartbeat rate returned to normal in oxygenated water within two hours. Limpets can survive for a short time in anoxic seawater; Grenon & Walker, (1981) found that in oxygen-free water limpets could survive up to 36 hours, although Marshall & McQuaid (1989) found a lower tolerance for *Patella granularis*, which survived up to 11 hours in anoxic water. Therefore, some individuals may survive for one week at an oxygen concentration of 2 mg/l. However, *Patella vulgata* is able to respire in air, so would only be exposed to low oxygen in the water column intermittently during periods of tidal immersion. In addition, in areas of wave exposure and moderately strong current flow low oxygen levels in the water are unlikely to persist

for very long.

Halichondria panicea has been reported to survive under oxygen levels as low as 0.5-4 % saturation (ca 0.05-0.4 mg/l) for up to 10 days (Mills *et al.*, 2014).

Sensitivity assessment. Based on evidence for the charatcerizing *Semibalanus balanoides, Halichondria panicea* and considering mitigation of de-oxygenation by water movements, this biotope is considered to have **'High'** resistance and **'High'** resilience (by default), and is, therefore **'Not sensitive'**.

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

This pressure relates to increased levels of nitrogen, phosphorus and silicon in the marine environment compared to background concentrations. The benchmark is set at compliance with WFD criteria for good status, based on nitrogen concentration (UKTAG, 2014). **'Not sensitive'** at the pressure benchmark that assumes compliance with good status as defined by the WFD.

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

As the biotope occurs in tide swept or wave exposed areas (Connor *et al.*, 2004), water movements will disperse organic matter reducing the level of exposure.

The animals found within the biotope may be able to utilise the input of organic matter as food, or are likely to be tolerant of inputs at the benchmark level. Cabral-Oliveira *et al.* (2014), found that filter feeders including the barnacle *Chthamalus montagui*, were more abundant at sites closer to a sewage treatment works, as they could utilise the organic matter inputs as food. On the same shores, higher abundances of juvenile *Patella* sp. and lower abundances of adults were found closer to sewage inputs, Cabral-Oliveira *et al.* (2014) suggested the structure of these populations was due to increased competition closer to the sewage outfalls.

In a recent review, assigning species to ecological groups based on tolerances to organic pollution, characterizing animal species*; Balanus crenatus and Spirobranchus triqueter* were assigned to AMBI Group II described as 'species indifferent to enrichment, always present in low densities with non-significant variations with time, from initial state, to slight unbalance' (Gittenberger & Van Loon, 2011).

Rose & Risk, 1985 described increase in abundance of the sponge *Cliona delitrix* in an organically polluted section of Grand Cayman fringing reef affected by the discharge of untreated faecal sewage. *Halichondria* occurs in harbours and estuaries (Ackers *et al.*, 1992) and may, therefore, tolerate high levels of organic carbon, although no specific evidence for this species was found, other sponges have been described in organically enriched environments. Fu *et al.* (2007) described *Hymeniacidon perleve* in aquaculture ecosystems in sterilized natural seawater with different concentrations of total organic carbon (TOC), at several concentrations between 52.9 and 335.13 mg/L). *Hymeniacidon perleve* removed 44–61% TOC during 24 h, with retention rates of ca. 0.19–1.06 mg/hr ·g-fresh sponge. *Hymeniacidon perleve* removed organic carbon excreted by *Fugu rubripes* with similar retention rates of ca. 0.15 mg/h · g-fresh sponge, and the sponge biomass increased by 22.8%.

Sensitivity assessment. It is not clear whether the pressure benchmark would lead to enrichment effects in this dynamic habitat. High water movements would disperse organic matter particles, mitigating the effect of this pressure. Based on the AMBI categorisation (Borja *et al*., 2000, Gittenberger & Van Loon, 2011), characterizing and associated species are assessed as 'Not Sensitive' to this pressure based on 'High' resistance and 'High' resilience as there is no impact to recover from. Although species within the biotope may be sensitive to gross organic pollution resulting from sewage disposal and aquaculture they are considered to have 'High' resistance to the pressure benchmark (which represents organic enrichment) and therefore 'High' resilience. The biotope is therefore considered to be 'Not Sensitive'.

⋔ 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

This biotope is characterized by the hard rock substratum to which the key characterizing species, spirorbids, barnacles and associated species can firmly attach to. A change to a sedimentary substratum would significantly alter the character of the biotope. More subtle changes in substratum type can also lead to indirect effects. Surface roughness, for example, is correlated with settlement in barnacles (Coombes *et al*., 2015). Spirorbids are also selective and will discriminate between different types of hard surface (James & Underwood, 1994). An artificial substratum may therefore not be equivalent to a natural rock reef habitat. An increase in mobile surfaces can also indirectly decrease suitable habitats. Shanks & Wright (1986) observed that limpet mortalities were much higher at sites where the supply of loose cobbles and pebbles were greater, leading to increased abrasion through wave action 'throwing' rocks onto surfaces. The biotope is therefore considered to have 'No' resistance to this pressure (based on a change to sediments), recovery is assessed as 'Very low', as the change at the pressure benchmark is permanent. Biotope sensitivity is therefore assessed as 'High'. As this biotope is found in caves, a change in topography from a cave to an open rock surface would also result in the loss of the biotope.

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 to biotopes occurring on bedrock.

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

The species characterizing this biotope are epifauna or epiflora occurring on rock and would be sensitive to the removal of the habitat. However, extraction of rock substratum is considered unlikely and this pressure is considered to be 'Not relevant' to hard substratum habitats.

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

The species characterizing this biotope occur on rock and, therefore, have no protection from surface abrasion. The effects of trampling (a source of abrasion) 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 and 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, Victora, Australia, found that in single step experiments 10 out of 67 barnacles, (*Chthamlus 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 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.

Hiscock (1983) noted that a community, under conditions of scour and abrasion from stones and boulders moved by storms, developed into a community similar to this biotope, consisting of fast growing species such as *Spirobranchus* (formerly *Pomatocero*s) *triqueter*. Off Chesil Bank, the epifaunal community dominated by *Spirobranchus* (as *Pomatoceros) triqueter* and *Balanus crenatus* decreased in cover in October as it was scoured away in winter storms, but recolonised in May to June (Gorzula, 1977). Warner (1985) reported that the community did not contain any persistent individuals but that recruitment was sufficiently predictable to result in a dynamic stability and a similar community, dominated by *Spirobranchus* (as *Pomatoceros) triqueter*, *Balanus crenatus* and *Electra pilosa*, (an encrusting bryozoan), was present in 1979, 1980 and 1983 (Riley and Ballerstedt, 2005).

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 an almost total destruction of local populations of limpets through abrasion by large rocks and boulders.

Sensitivity assessment. The impact of surface abrasion will depend on the footprint, duration and magnitude of the pressure, however persistent abrasion from scouring could result in a change to the similar biotope LR.FLR.CvOv.ScrFa (Connor *et al.*, 2004). The evidence for the effects of trampling and scour on barnacles suggest that resistance, to a single abrasion event is **'Low'** and recovery is **'High'**. Sensitivity is assessed as **'Low'**.

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

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

Changes in suspended solids (water clarity)	Medium	High	Low
	Q: Low A: NR C: NR	Q: High A: High C: High	Q: Low A: Low C: Low

This biotope tends to occur above scoured habitats. An increase in scour could result in a change in biotope to the more faunally impoverished LR.FLR.CvOv.ScrFa. However, given the proximity to the this scoured biotope, it is likely, depending on local sediment supply, that the biotope is exposed to intermittent episodes of high-levels of suspended solids as local sediments are re-mobilised and transported. A significant increase in suspended solids may result in smothering (see siltation pressures) where these are deposited. Based on Cole *et al*. (1999) and Devlin *et al*. (2008) this biotope is considered to experience intermediate turbidity (10-100 mg/l) based on UK TAG (2014). An increase at the pressure benchmark refers to a change to medium turbidity (100-300 mg/l) and a decrease is assessed as a change to clear (<10 mg/l) based on UK TAG (2014).

An increase in turbidity could be beneficial if the suspended particles are composed of organic matter, however, high levels of suspended solids with increased inorganic particles may reduce filter feeding efficiencies. A reduction in suspended solids will reduce food availability for filter feeding species in the biotope (where the solids are organic), although effects are not likely to be lethal over the course of a year. A reduction in light penetration could also reduce the growth rate of phytoplankton and so limit zooplankton levels. However, light penetration itself is unlikely to be an important factor as both *Balanus crenatus* and *Spirobranchus triqueter* are recorded from the lower eulittoral or the lower circalittoral.

Barnes and Bagenal (1951) found that growth rate of *Balanus crenatus* epizoic on *Nephrops norvegicus* was considerably slower than animals on raft exposed panels. This was attributed to reduced currents and increased silt loading of water in the immediate vicinity of *Nephrops norvegicus*. In dredge disposal areas in the Weser estuary, Germany, where turbidity is 35% above the natural rate of 10-100 mg/l, the abundance of *Balanus crenatus* was lower than in reference areas (Witt *et al*., 2004). Separating the effect of increased suspended solids from increased sedimentation and changes in sediment from sediment dumping is problematic, however (Witt *et*

al., 2004). Balanids may stop filtration after silt layers of a few millimetres have been discharged (Witt *et al.*, 2004), as the feeding apparatus is very close to the sediment surface.

A significant decrease in suspended organic particles may reduce food input to the biotope resulting in reduced growth and fecundity of barnacles and encrusting sponges. However, local primary productivity may be enhanced where suspended sediments decrease, increasing food supply.

Gyory *et al.*, (2013) found that increased turbidity triggered the release of larvae by *Semibalanus balanoides*, a response which may allow the larval release to be timed with high levels of phytoplankton and at times where predation on larvae may be lowered due to the concentration of particles. Storm events that stir up sediments are also associated with larval release (Gyory & Pineda, 2011).

Sensitivity assessment. The increased scour associated with an increase in turbidity would probably result in increased mortality among the characterizing species. Overall biotope resistance is assessed as **'Medium'** to an increase in suspended solids. Resilience is categorised as **'High'** and sensitivity is **'Low'.**

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

LR.FLR.CvOv.FaCr tends to occur above biotopes subject to scouring from abrasion by mobile sediments (Connor *et al.*, 2004) and is, therefore (being on cave walls and ceilings), unlikely to be affected by smothering in most cases. Increased scour is probably the most important factor when considering sensitivity to deposition of sediment. The characterizing species occur in biotopes subject to sedimentation and scour (such as the more impoverished LR.FLR.CvOv.ScrFa) and are therefore likely to tolerate intermittent episodes of fine sediment movement and deposition, however, decline in abundance is likely given the respective biotope descriptions (Connor *et al.*, 2004) . Removal of the sediments by wave action and tidal currents would result in considerable scour. The effect of this pressure will be mediated by the length of exposure to the deposit and the nature of the deposit.

Holme & Wilson (1985) described a *Pomatoceros-Balanus* assemblage on 'hard surfaces subjected to periodic sever scour and 'deep submergence by sand or gravel' in the English Channel. They inferred that the *Pomatoceros-Balanus* assemblage was restricted to fast-growing settlers able to establish themselves in short periods of stability during summer months (Holme & Wilson 1985), as all fauna were removed in the winter months. Barnacles may stop filtration after silt layers of a few millimetres have been discharged as the feeding apparatus is very close to the sediment surface (Witt *et al.*, 2004). In dredge disposal areas in the Weser estuary, Germany, where the modelled exposure to sedimentation was 10mm for 25 days, with the centre of the disposal ground exposed to 65 mm for several hours before dispersal, *Balanus crenatus* declined in abundance compared to reference areas. (Witt *et al.*, 2004). However, separating the effect of sedimentation from increased suspended solids and changes in sediment from sediment dumping was problematic (Witt *et al.*, 2004).

Field observations and laboratory experiments have highlighted the sensitivity of limpets to sediment deposition (see also the 'heavy' siltation pressure for further information). Airoldi & Hawkins (2007) tested the effects of different grain sizes and deposit thickness in laboratory experiments using *Patella vulgata*. Sediments were added as a 'fine' rain to achieve deposit

thicknesses of approximately 1mm, 2 mm, and 4 mm in controlled experiments and grazing and mortality observed over 8-12 days. Limpets were more sensitive to sediments with a higher faction of fines (67% silt) than coarse (58% sand). Coarse sediments of thicknesses approximately 1, 2 and 4 mm decreased grazing activity by 35, 45 and 50 % respectively. At 1 and 2 mm thicknesses, fine sediments decreased grazing by 40 and 77 %. The addition of approximately 4 mm of fine sediment completely inhibited grazing. Limpets tried to escape the sediment but lost attachment and died after a few days (Airoldi & Hawkins, 2007).

Observations on exposed and sheltered shores with patches of sediment around Plymouth in the south west of England found that *Patella vulgata* abundances were higher where deposits were absent. The limpets were locally absent in plots with 50-65% sediment cover (Airoldi & Hawkins, 2007). Littler *et al.* (1983) found that the another limpet species, *Lottia gigantea* on southern Californian shores was restricted to refuges from sand burial on shores subject to periodic inundation by sands.

Sensitivity assessment. Sensitivity to this pressure will be mediated by site-specific hydrodynamic conditions and topography of the biotope. Whilst smothering is unlikely, given that the biotope typically occurs on cave walls and ceilings, scour and abrasion are likely to result in mortality. Resistance is assessed as **'Low'** as the exposure to abrasion and scour is likely to result in the decline of the characterizing species (however, the impact may be mitigated by rapid removal of the deposit). Resilience is assessed as **'High'**. Biotope sensitivity is therefore assessed as **'Low'.**

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

LR.FLR.CvOv.FaCr tends to occur above biotopes subject to scouring from abrasion by mobile sediments (Connor *et al.*, 2004) and is, therefore, being on cave walls and ceilings, unlikely to be affected by smothering in most cases. Increased scour is probably the most important factor when considering sensitivity to deposition of sediment. The characterizing species occur in biotopes subject to sedimentation and scour (such as the more impoverished LR.FLR.CvOv.ScrFa) and are therefore likely to tolerate intermittent episodes of fine sediment movement and deposition, however, decline in abundance is likely given the respective biotope descriptions (Connor *et al.*, 2004) . Removal of the sediments by wave action and tidal currents would result in considerable scour. The effect of this pressure will be mediated by the length of exposure to the deposit and the nature of the deposit.

As small, sessile species attached to the substratum, siltation at the pressure benchmark would bury *barnacles and spirorbids*. The lower limits of *Semibalanus balanoides* (as *Balanus balanoides*) appear to be set by levels of sand inundation on sand-affected rocky shores in New Hampshire (Daly & Mathieson, 1977. Holme and Wilson (1985) described a *Pomatoceros-Balanus* assemblage on 'hard surfaces subjected to periodic sever scour and 'deep submergence by sand or gravel' in the English Channel. They inferred that the *Pomatoceros-Balanus* assemblage was restricted to fast-growing settlers able to establish themselves in short periods of stability during summer months (Holme and Wilson, 1985), as all fauna were removed in the winter months. Barnacles may stop filtration after silt layers of a few millimetres have been discharged as the feeding apparatus is very close to the sediment surface (Witt *et al.*, 2004). In dredge disposal areas in the Weser estuary, Germany, where the modelled exposure to sedimentation was 10mm for 25 days, with the centre of the disposal ground exposed to 65 mm for several hours before dispersal, *Balanus crenatus* declined in abundance compared to reference areas. (Witt *et al.*, 2004). However,

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Field observations and laboratory experiments have highlighted the sensitivity of limpets to sediment deposition (see also the 'heavy' siltation pressure for further information). Airoldi & Hawkins (2007) tested the effects of different grain sizes and deposit thickness in laboratory experiments using *Patella vulgata*. Sediments were added as a 'fine' rain to achieve deposit thicknesses of approximately 1mm, 2 mm, and 4 mm in controlled experiments and grazing and mortality observed over 8-12 days. Limpets were more sensitive to sediments with a higher fraction of fines (67% silt) than coarse (58% sand). Coarse sediments of thicknesses approximately 1, 2 and 4 mm decreased grazing activity by 35, 45 and 50 % respectively. At 1 and 2 mm thicknesses, fine sediments decreased grazing by 40 and 77 %. The addition of approximately 4 mm of fine sediment completely inhibited grazing. Limpets tried to escape the sediment but lost attachment and died after a few days (Airoldi & Hawkins, 2007). Observations on exposed and sheltered shores with patches of sediment around Plymouth in the south west of England found that *Patella vulgata* abundances were higher where deposits were absent. The limpets were locally absent in plots with 50-65% sediment cover (Airoldi & Hawkins, 2007). Littler *et al.* (1983) found that another limpet species, *Lottia gigantea* on southern Californian shores was restricted to refuges from sand burial on shores subject to periodic inundation by sands.

Sensitivity assessment. Sensitivity to this pressure will be mediated by site-specific hydrodynamic conditions and topography of the biotope. Whilst smothering is unlikely, given that the biotope typically occurs on cave walls and ceilings, scour and abrasion are likely to result in mortality. Resistance is assessed as **'Low'** as the exposure to abrasion and scour is likely to result in the decline of the characterizing species (however, the impact may be mitigated by rapid removal of the deposit). Resilience is assessed as **'High'**. Biotope sensitivity is therefore assessed as **'Low'.**

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.

. Thompson *et al.* (2004) demonstrated that *Semibalanus balanoides*, kept in aquaria, ingested microplastics within a few days. However, the effects of the microplastics on the health of exposed individuals have not been identified. There is currently no evidence to assess the level of impact.

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

'No evidence'.

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

'Not relevant'. Wave action on exposed shores is likely to generate high levels of underwater noise. Other sources are not considered likely to result in effects on the biotope.

Introduction of light or shading

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

Light penetration is a key factor structuring the cave biotope. Encrusting corallines and other shade-tolerant algae grow closer to the entrance where light availability allows. Encrusting corallines can occur in deeper water than other algae where light penetration is limited. Samples of *Lithophyllum impressum* suspended from a raft and shaded (50-75% light reduction) continued to grow over two years (Dethier, 1994). An increase in light in the spectrum that supports photosynthesis may allow algae including *Rhodochorton purpureum* and *Pilinia maritima* which are found within caves (Connor *et al.*, 2004) to colonise more surface area, altering the structure of the biotope.

Semibalanus balanoides sheltered from the sun grew bigger than unshaded individuals (Hatton, 1938; cited in Wethey, 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 population level as a result. There is, therefore, 'No evidence' on which to base an assessment.

Jones *et al.* (2012) compiled a report on the monitoring of sponges around Skomer Island and found that many sponges, particularly encrusting species, preferred vertical or shaded bedrock to open, light surfaces, which may be explained through competition with algal species.

Sensitivity assessment. The key characterizing faunal species colonize a broad range of light environments, from intertidal to deeper sub tidal and shaded understorey habitats and are considered to be unaffected by increased shade or more light penetration. However, an increase in light in the spectrum that supports photosynthesis may increase algal growth altering the character of the biotope. Some specialist cave species may colonize depending on the presence of source populations. The biotope is therefore considered to have **'Low'** resistance and **'High'** resilience following restoration of typical conditions (as the algae are likely to be lost). Sensitivity is therefore considered to be **'Low'**.

Barrier to species movement

High	High	Not sensitive
Q: Low A: NR C: NR	Q: High A: High C: High	Q: Low A: Low C: Low

No direct evidence was found to assess this pressure. Barriers that reduce the degree of tidal excursion may alter larval supply to suitable habitats from source populations. Conversely, the

presence of barriers may enhance local population supply by preventing the loss of larvae from enclosed habitats. As the larvae of Balanus crenatus and Semibalanus balanoides and other species such as Patella vulgata are planktonic and are transported by water movements, barriers that reduce the degree of tidal excursion may alter larval supply to suitable habitats from source populations. However, the presence of barriers may enhance local population supply by preventing the loss of larvae from enclosed habitats.

It should be noted that examples of this biotope require tidal surge for moisture to maintain species abundance, however, this is considered an indirect effect and only the species movement is considered. Resistance to this pressure is assessed as **'High'** and resilience as **'High'** by default. This biotope is therefore considered to be **'Not sensitive'**.

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

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

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

Many of the animal species within the biotope probably respond to light levels, detecting shade and shadow to avoid predators and day length in their behavioural or reproductive strategies. However, their visual acuity is probably very limited and they are unlikely to respond to visual disturbance at the benchmark level. This pressure is, therefore, assessed as **'Not relevant'**.

Balanus crenatus possesses a rudimentary eye and can detect and respond to sudden shading which may be an anti-predator defence (Forbes *et al*., 1971). *Balanus crenatus* tend to orient themselves when settling, with the least light sensitive area directed towards the light (Forbes *et al*., 1971), so that the most sensitive area can detect shading from predator movements in the area where light availability is lower (Forbes *et al*., 1971).

🐚 Biological Pressures

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

Important characterizing species within this biotope are not cultivated or translocated. This pressure is, therefore, considered **'Not relevant'** to this biotope group.

Introduction or spread of invasive non-indigenous species	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

Scour in this biotope will probably limit the establishment of all but the most scour resistant

invasive non-indigenous species (INIS) and no direct evidence was found for effects of INIS on this biotope. The low levels of light within this biotope, particularly the rear walls of caves, are considered to also inhibit invasive algal species.

The Australasian barnacle *Austrominius* (previously *Elminius*) *modestus* was introduced to British waters on ships during the second world war. Increased warming has allowed the Australian barnacle *Austrominius* (formerly, *Elminiusi) modestus,* to dominate sites previously occupied by *Semibalanus balanoides* and *Balanus crenatus* (Witte, 2010). However, on settlement panels deployed in SW Ireland, *Austrominius modestus* initially dominated panels in the lower subtidal but post-recruitment mortality over a year allowed *Balanus crenatus* to become the dominant barnacle (Watson *et al*., 2005). *Balanus crenatus* and *Austrominius modestus* have shown recruitment differences which may alter the seasonal dominance patterns (Witte *et al*., 2010). In general, 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).

Two non-native spirorbids – *Dexiospira oshoroensis* and *Pileolaria rosepigmentata* - were found on the non-native algae *Sargassum muticum* in Portsmouth (Knight-Jones *et al*., 1975). Invasive tubeworms are reported from UK harbours (Thorp *et al*., 1986) and are likely to be well established in areas with large volumes of ship traffic.

The tunicates *Didemnum vexillum* and *Asterocarpa humilis*, the hydroid *Schizoporella japonica* and the bryozoan *Watersipora subatra* (Bishop, 2012c, Bishop, 2015a and b; Wood, 2015) are currently only recorded from artificial hard substratum in the UK and it is not clear what their established range and impacts in the UK would be. *Didemnum vexillum* occurs in tide pools in other areas where it has become established (Bishop, 2012c) and can have substantial effects on communities, similarly the tunicates *Corella eumycota* and *Botrylloides violaceus* can smother rock habitats (Bishop, 2011b and 2012b).

Sensitivity assessment. Overall, there is **'No evidence'** of this biotope being adversely affected by non-native species. It should be noted that replacement of native barnacles and spirorbids by non-natives alters the identity of the species present but has little impact on biotope character and function.

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

Gochfeld *et al.* (2012) found that diseased sponges hosted significantly different bacterial assemblages compared to healthy sponges, with diseased sponges also exhibiting a significant decline in sponge mass and protein content. Sponge disease epidemics can have serious long-term effects on sponge populations, especially in long-lived, slow-growing species (Webster, 2007). Numerous sponge populations have been brought to the brink of extinction including cases in the Caribbean (with 70-95% disappearance of sponge specimens) (Galstoff,1942) and the Mediterranean (Vacelet,1994; Gaino *et al*.,1992). Decaying patches and white bacterial film were reported in *Haliclona oculata* and *Halichondria panicea* in North Wales, 1988-89 (Webster, 2007). Specimens of *Cliona* spp. exhibited blackened damage since 2013 in Skomer. Preliminary results have shown that clean, fouled and blackened *Cliona* all have very different bacterial communities. The blackened *Cliona* are effectively dead and have a bacterial community similar to marine

sediments. The fouled *Cliona* have a very distinct bacterial community that may suggest a specific pathogen caused the effect (Burton, pers comm; Preston & Burton, 2015).

The charazing species *Semibalanus balanoides* are considered subject to persistent, low levels of infection by pathogens and parasites. Barnacles are parasitised by a variety of organisms and, in particular, the cryptoniscid isopod *Hemioniscus balani*, in which heavy infestation can cause castration of the barnacle. At usual levels of infestation, these are not considered to lead to high levels of mortality. The associated species *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 ciliate* and a siliceous sponge *Cliona celata*.

Sensitivity assessment. Sponge diseases have caused limited mortality in some species in the British Isles, although mass mortality and even extinction have been reported further afield. However, **'No evidence'** of mortality due to disease could be found for the the important characterizing species of this biotope.

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

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The sensitivity assessment for this pressure considers any biological/ecological effects resulting from the removal of target species on this biotope. Limpets may be gathered recreationally for consumption but the removal of this species is not considered to alter the character of the biotope through its loss as shade, rather than grazing, are the key factors limiting the presence of algae (Connor *et al.*, 2004). No commercial application or harvesting of other characterizing or associated species is described in the literature and this pressure is therefore considered to be **'Not relevant'.**

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

Incidental removal of the important characterizing species would alter the character of the biotope, resulting in reclassification and the loss of species richness. The ecological services such as primary and secondary production, provided by characterizing and associated species, would also be lost. As most species present in this biotope are relatively large, conspicuous and either sedentary or attached to rock surfaces that have little protection against removal.

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

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