Green algal films on upper and mid-shore cave walls and ceilings

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

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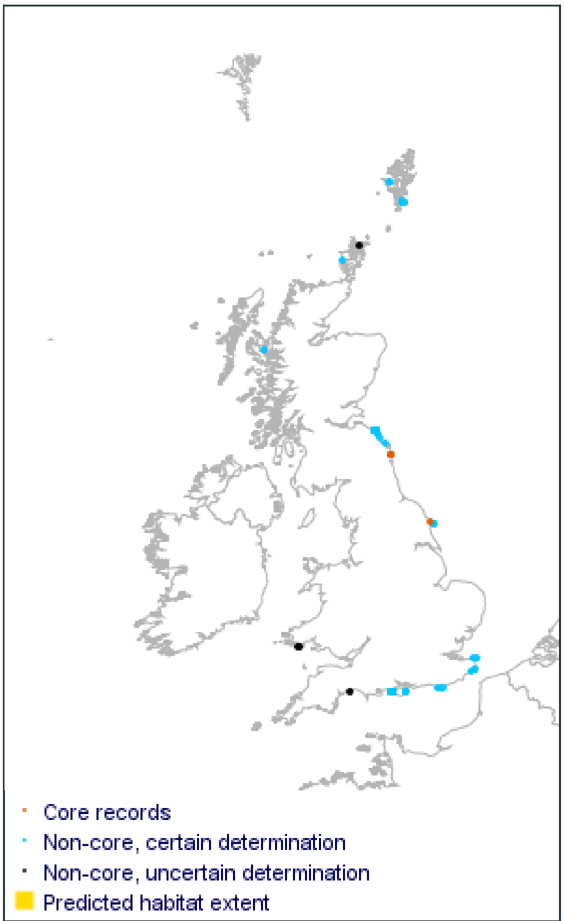
Green algal films on upper and mid-shore cave walls and ceilings
Photographer: Rohan Holt



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

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

Summary

UK and Ireland classification

EUNIS 2008	A1.442	Green algal films on upper and mid-shore cave walls and ceilings
JNCC 2015	LR.FLR.CvOv.GCv	Green algal films on upper and mid-shore cave walls and ceilings
JNCC 2004	LR.FLR.CvOv.GCv	Green algal films on upper and mid-shore cave walls and ceilings
1997 Biotope		

Description

The upper walls and ceilings of upper and mid-shore hard and soft rock (chalk) dominated by a band of green algal films (or 'stains'). Other encrusting algae including the non-calcified *Hildenbrandia rubra* may be present. In chalk caves, on the east and south-east coasts of England, a distinctive assemblage of species occurs, including the brown alga *Pleurocladia lacustris* (syn. *Pilinia maritima*) and the bright green algae *Pseudendoclonium submarinum* and *Entocladia perforans* that often covers the cave ceilings. Fauna is generally sparse and limited to limpets such as *Patella vulgata* and the winkle *Littorina saxatilis*. The species forming a green algal film that covers upper shore caves in Berwickshire were not identified. More information is required to validate this biotope description. This biotope is situated above the RhoCla or VmucHil zone, extending to cover the upper walls and ceilings of caves. GCv can be found at the entrances to caves and through to the darkest areas at the back and is often found above a zone of RhoPle. In hard rock caves, however, the green and brown algae (RhoPle) or Haptophyceae (ChrHap) occur as separate zones or GCv may occur on its own. (Information from Connor *et al*., 2004; JNCC, 2015).

Depth range

Upper shore

Additional information

Little information on this biotope was found. The bright green algae *Pseudendoclonium submarinum* (previously described by Anand (1936, 1937a) as *Endoderma perforans*) and *Entocladia perforans* occur on the upper walls and ceilings of caves, especially chalk caves. The description fits the 'Endoderma' belt described by Anand (1937b&c) that sits above the Chrysophyceae and Haptophyceae belt. However, the two bands may overlap, so that the Chrysophyceae *Chrysotila stipitata* may grow over the 'Endoderma' belt while the 'Endoderma' belt may extend into the Chrysophyceae belts in periods of drought (Anand, 1937b&c). Therefore for the purpose of this review, the 'green algal films' are assumed to equate to the 'Endoderma' belt described by Anand (1937b&c) and recorded in chalk and hard rock caves by Norton *et al.* (1971), Tittley & Shaw (1980), Tittley (1988), Fowler & Tittley (1993).

Listed By

- none -

Further information sources

Search on:

G G G JNCC

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

This review assumes that the green algal films that characterize this biotope (LRFLR.CvOv.GCv) correspond to the 'Endoderma' belt described by Anand (1937b&c). This biotope may overlap with the Chrysophyceae and Haptophyceae belt (LR.FLR.CvOv.ChrHap) on chalk cliffs and caves, as the 'Endoderma' belt may extend into the 'Chrysophyceae' belt in periods of drought while the Chrysophyceae *Chrysotila* spp. may grow over the 'Endoderma' belt (*Pseudendoclonium submarinum)* where adequate sea spray was present. However, *Pseudendoclonium submarinum* is also present in the 'Chrysophyceae' belt (the Chrysophyceae-Endoderma-Lyngbya community) and in moist shaded conditions, e.g. during winter, in recesses or on the ceilings of caves and tunnels *Pseudendoclonium submarinum* 'gains the upper hand (Anand, 1937b) and turns the 'Chrysophyceae' belt green. *Pseudendoclonium submarinum* also grows in other conditions, such as on hard rock or artificial substata (e.g. timber, bridge pilings) (Humm & Bert, 1979). *Pseudendoclonium submarinum* may also occur in communities with blue-green algae e.g. *Entophysalis deusta*, which can grow over the green algal film (Tittley, 1988). *Hildenbrandia rubra* is a common species that forms conspicuous patches on stable rock (and stones) on upper littoral cave walls but is also found in the littoral and sublittoral to 12 m (Irvine & Chamberlain, 1994). The arthropod community of supralittoral rock (red mites, insects, centipedes, and spiders) are mobile species that are found throughout the supralittoral and are not dependent on this biotope. Therefore, the bright green algae *Pseudendoclonium submarinum* and *Entocladia perforans* have been used to indicate the sensitivity of this biotope, with reference to detailed studies on the ecology of the chalk cliff and cave algal communities by Anand (1937,b&c), Tittley & Shaw (1980), Tittley (1988), Fowler & Tittley (1993).

Resilience and recovery rates of habitat

Pseudendoclonium submarinum and *Entocladia perforans* are Ulvales (Chlorophyta). Anand (1937b) reported that *Pseudendoclonium submarinum* (as *Endoderma perforans*) formed small clusters of cells from which short filaments arise. In moist shaded conditions the filaments are longer and the growth more conspicuous. The filaments grow into chalk, and extend into the algal mat of the Chrysophyceae belt and along the surface of and may aggregate into tooth-like bundles (Anand, 1937b). In moist conditions, the *Pseudendoclonium submarinum* turns the upper part of Chrysophyceae belt (the Chrysophyceae-Endoderma-Lyngbya community) green. Anand (1937b) also noted that *Pseudendoclonium submarinum* was an early colonizer, that the was overgrown by *Chyrsotila* spp. to form the Chrysophyceae belt.

Sexual reproduction in Ulvales is isomorphic and diplohaplontic (Van den Hoek *et al.*, 1995), so that the haploid sporophyte and diploid gametophyte are identical in appearance. Both phases produce numerous flagellated gametes. However, sexual reproduction is not known *Pseudendoclonium submarinum*, which produces motile zoospores, non-motile aplanospores and dormant resting stages (akinetes) by asexual reproduction (Guiry & Guiry, 2016). No information on reproduction in *Endocladia* was found.

Resilience assessment. The characteristic flora produce highly motile zoospores, as well as resting stages. *Pseudendoclonium submarinum* is probably also widespread and found on a range of substrata. In California, USA, Seapy & littler (1982) reported that the *Endoladia muricata* and blue-green algae band on Santa Cruz Island died back but were not lost seasonally in the winter months due to aerial exposure, especially in the presence of hot dry winds. The *Endoladia muricata* and blue-green algae band recovered from a substantial die back in February 1976, to exceed its formaer abundnace by October 1976 (ca 6 months) only to die back again in February 1977. Although the species differ from the 'Endoderma' band, their life history charactersitcs are probalby similar. Therefore, recruitment and recolonization are probably rapid, within a one or two years, and resilience is probably **High** even where the entire community is removed. However, no direct evidence of recovery was found and the assessment is based on life history characteristics so that confidence in the assessment is Low.

Hydrological Pressures

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

Anand (1937c) examined the range of temperatures experienced by chalk cliff algal communities. The *Pseudendoclonium submarinum* ('Endoderma') belt was exposed to temperatures slightly less than air (since the cliff face heats up slowly) but similar variability in temperature to that of the air (i.e. between 4.9 and 22.6°C in spring and summer). Anand (1937c) suggested that the 'Endoderma' belt was thin and closed adherent to the substratum so that it benefited from the thermal buffering effect of the rock itself. Chalk also retain moisture. However, the 'Endoderma' belt dominated in shaded and moist environments, such as chalk caves and tunnels walls and ceilings, which are protected from direct sunlight, and probably exhibit a smaller range of temperatures than cliff faces. Seapy & Littler (1982) reported the seasonal die back of a similar *Endocladia* and blue-green algal band, on intertidal rock due to desiccation stress in the winter months on Santa Cruz Island, California. The die back was substantial when the intertidal was exposed to dry hot winds 10°C higher than average, in the winter of 1975-76. However, the band exceeded its prior cover within 6 months (Seapy & Littler, 1982).

Sensitivity assessment. Therefore, an increase in annual temperatures (at the benchmark level) is likely to increase the risk of desiccation and exposure to high temperatures during summer depending on its shelter and aspect. However, populations in caves are likely to be protected from direct sunlight. In addition, Anand (19737c) noted that when the 'Chrysophyceae' belt was cracked and peeling due to desiccation, the 'Endoderma' belt could extend its range. Hence, a resistance of **High**. Therefore, resilience is **High** and the biotope is recorded as **Not sensitive** at the benchmark level.

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

Anand (1937b&c) reported that light brown or white patches appeared in the 'Chrysophyceae' mat during winter due to frost. Anand (1937b) noted that winter weather with reduced light favoured the Endoderma belt. However, little other information concerning low temperatures was found. A decrease in annual winter temperatures is likely to increase the risk of frost, however, a reduction in average summer temperatures will reduce the risk of desiccation. In addition, caves may gain some protection from frost, depending on their size and aspect. Therefore, **resistance** is probably **High,** so that resilience is also **High** and **Not sensitive** has been recorded at the benchmark level.

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

Although not covered by seawater, the upper littoral fringe and supralittoral experience a wide range of salinities due to the evaporation of wave splash and spray, resulting in high salt concentrations, and exposure to rain and freshwater runoff. For example, Anand (1937c) showed that the salt concentration in the 'Chrysophyceae' belt was higher than in the *Ulva* sp. belt (lower on the shore) but (due to water retention) did not experience as great an increase in salt concentration once the tide fell. The 'Chrysophyceae' belt the salt concentration may be approximately three times that of seawater (Anand, 1937c). *Pseudendoclonium submarinum* (as *Endoderma perforans*) is a constant part of the 'Chrysophyceae' belt, growing within the belt and is, therefore, exposed to similar salinity conditions. However, Anand (1937c) was unable to test the salinity range within the 'Endoderma' belt directly but noted that the 'Endoderma' was rarely wetted by spray except in rough weather, so that is was probably less exposed to 'salt' than the Chrysophyceae' belt (Anand, 1937b&c). In addition, caves are likely to retain moisture and be more humid than cliff faces as they are protected from wind and sunlight and direct rainfall, although rainwater could potentially percolate through soft rock. Therefore, this biotope is probably resistant to changes in salinity comparable to the benchmark (i.e. >40 PSU). Therefore, a resistance of **High** is suggested, so that resilience is also **High** and **Not sensitive** is recorded.

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

Although not covered by seawater, the upper littoral fringe and supralittoral experience a wide range of salinities due to the evaporation of wave splash and spray, resulting in high salt concentrations, and exposure to rain and freshwater runoff. For example, Anand (1937c) showed that the salt concentration in the 'Chrysophyceae' belt was higher than in the *Ulva* sp. belt (lower on the shore) but (due to water retention) did not experience as great an increase in salt concentration once the tide fell. The 'Chrysophyceae' belt the salt concentration may be approximately three times that of seawater (Anand, 1937c). *Pseudendoclonium submarinum* (as *Endoderma perforans*) is a constant part of the 'Chrysophyceae' belt, growing within the belt and is, therefore, exposed to similar salinity conditions. However, Anand (1937c) was unable to test the salinity range within the 'Endoderma' belt directly but noted that the 'Endoderma' was rarely wetted by spray except in rough weather, so that is was probably less exposed to 'salt' than the Chrysophyceae' belt (Anand, 1937b&c). In addition, caves are likely to retain moisture and be more humid than cliff faces as they are protected from wind and sunlight and direct rainfall, although rainwater could potentially percolate through soft rock. Therefore, this biotope is probably resistant to changes in salinity comparable to the benchmark (i.e. >40 PSU). Therefore, a resistance of **High** is suggested, so that resilience is also **High** and **Not sensitive** is recorded at the benchmark level.

Water flow (tidal current) changes (local)	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 upper littoral fringe and supralittoral are rarely if ever inundated. Tidal influence in mid-littoral to supralittoral caves is probably is probably limited to the floor and sides of the caves, and the upper walls and ceilings only receive spray and splash. Therefore, the biotope is unlikely to be affected by water flow as described by the benchmark. Therefore, the pressure is **Not relevant**.

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

Anand (1937c) examined the volumes of water and spray received by the littoral fringe and supralittoral on chalk cliffs. He concluded that the 'Chrysophyceae' belt received occasional spray and rarely very much. In calm weather in summer periods the belt was subject to periods of drought of up to three days occasionally separated by brief periods of spray. The 'Endocladia' belt was rarely wetted by spray except in rough weather at spring tides and experienced periods of drought of up to three days and yet still extended to high levels (8-10 m). The 'Endocladia' belt showed more conspicuous growth in tunnels and recesses where waves break and spray reached higher levels (Annand, 1937c). It should be remembered that chalk retains moisture and may offset the desiccation experienced at different shore height. Anand (1937c) also noted that rainfall contributed to moisture but did not influence zonation (height on the shore) as it affected the entire shore, although caves may be protected from direct rainfall (depending on aspect) and only receive freshwater via percolation. Caves (and tunnels) retains moisture and are therefore dependent on wave action for spray and splash and rainfall to maintain the humidity of the atmosphere.

A decrease in emergence equivalent would expose the habitat to an increased level of spray. However, decreased emergence will allow the algal communities to colonize further up the shore so that the entire zonation (see habitat complexity) will probably move up the shore. Anand (1937c) noted that in caves and tunnels where waves break and spray reaches high levels, the 'Endoderma' belt showed more conspicuous growth.

An increase in emergence will result in a reduction in the height reached by wave splash and spray. Hence, the height of the algal communities in the littoral fringe and supralittoral will also be reduced, resulting in the biotope effectively moving down the shore. Some species particularly abundant in more moist conditions may be lost. Therefore, the extent or abundance of the biotope is likely to be reduced, although mitigated by the humid cave environment, and a resistance of **Medium** has been recorded. Once prior conditions return, recovery is likely to be rapid so that resilience is probably **High** and sensitivity **Low**.

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

The height and extent of the littoral fringe and supralittoral, and hence the communities they support is dependent on wave wash, splash and spray, and therefore, wave exposure. Anand (1937b&c) noted that the *Pseudendoclonium submarinum* belt could reach up to 8-10 m above high water but in caves or recesses where waves break and create more spray the algal communities could extend higher up the shore. Increased wave exposure is likely to increase the overall height of the littoral fringe or supralittoral and increase the height and extent of the associated algal communities. Increased spray may also allow a more diverse community to develop resulting in a rise in species richness. A decrease in wave exposure is likely to reduce the height of the littoral fringe or supralittoral and hence the extent of its associated algal communities. However, as the biotope is typical of moderately wave exposed or wave sheltered conditions, a 3-5% change in significant wave height (the benchmark) is unlikely to have a significant effect. Therefore, resistance and resilience are considered **High**, and the biotope is probably **Not sensitive** at the benchmark level.

Chemical Pressures

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

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

Cole *et al.* (1999) suggested that Pb, Zn, Ni and As were probably very toxic to algae but no direct evidence of the effects on this biotope was found. However, this biotope is considered to be This pressure is **Not assessed** but evidence is presented where available.

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**. No evidence concerning the effects of hydrocarbons or oil spills on chalk cliff or cave green algal communities was found.

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.

No information on the effects of synthetic chemicals on soft or hard rock algal film communities was found. However, 1µg/l TBT was shown to significantly reduce growth of the diatoms *Pavlova lutheri* and *Dunaliella tertiolecta* and *Skeletonema costatum* would not grow at 100 ng/l TBT. All species died at 5 µg/l TBT (Beaumont & Newman, 1986; Bryan & Gibbs, 1991). Bryan & Gibbs (1991) reported that TBT suppressed growth of the *Skeletonema costatum* (EC_{50} 350ng/l) and *Thalassiosira pseudonana* (EC_{50} 1.15 µg/l). Cole *et al.* (1999) reported that TBT impaired the development of motile spores of green macroalgae (5 day EC_{50} of 1 ng/l TBT), which were considered the most intolerant phase of their life cycle. In addition, Cole *et al.* (1999) suggested that the herbicides Atrazine, Simazine, Diuron, Linuron and the insecticide Dimethoate were probably very toxic to algae.

Therefore, it is probable that soft or hard rock algal film communities are intolerant of synthetic chemicals, in particular, herbicides that may be contained in runoff (during heavy rains) from adjacent agricultural land.

Radionuclide contamination	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence was found.

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

This pressure is **Not assessed**.

De-oxygenation	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

The littoral fringe and supralittoral, and cave ceilings are rarely inundated and are, therefore, permanently exposed to the air. The biotope is unlikely to be exposed to deoxygenated conditions.

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

Maritime cliff plant and algae communities are probably nutrient poor, i.e. lack nutrients. An increase in nutrients in the form of runoff from adjacent agricultural land may benefit the communities. However, the opportunistic filamentous algae such as *Ulothrix* sp. and *Urospora* sp. may overgrow the 'Endoderma' or 'Chrysophyceae' belts, but *Pseudendoclonium submarinum* may benefit from nutrient enrichment, resulting in the dominance of a few species at the expense of a more diverse community. However, no evidence concerning the effects of nutrient enrichment on these communities was found.

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

Maritime cliff plant and algae communities are probably nutrient poor, i.e. lack nutrients. An increase in nutrients in the form of runoff from adjacent agricultural land may benefit the communities. However, the opportunistic filamentous algae such as *Ulothrix* sp. and *Urospora* sp. may overgrow the 'Endoderma' or 'Chrysophyceae' belts, but *Pseudendoclonium submarinum* may benefit from nutrient enrichment, resulting in the dominance of a few species at the expense of a more diverse community. However, no evidence concerning the effects of nutrient enrichment on these communities was found.

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

Urban and industrial development in south east UK, resulted in a need for coastal defence works to stabilise cliffs and reduce coastal erosion. The construction of sea walls at the base of cliffs cuts off caves and tunnels from the inundation by the sea and prevents sea wash or spray reaching the cliff face. The cliff face may also be scarped and straightened to reduce falls and gullies torn down, resulting in loss of substratum (Fowler & Tittley, 1993). Tittley *et al.* (1998) surveyed chalk cliffs throughout England and revealed that 56% of coastal chalk in Kent and 33% in Sussex had been modified by coastal defence and other works. On the Isle of Thanet, this increased to 74% and had resulted in the loss of a wide range of microhabitats on the upper shore and the removal of splash-zone communities. Elsewhere in England, coastal chalk remains in a largely natural state (Anon, 1999e, Tittley *et al.*, 1988). Fowler & Tittley (1993) noted that the brown algae *Kuetzingiella holmesii*, characteristic of cave communities and *Pleurocladia lacustris* had not been re-recorded since the 1930s. The resultant sea walls do not support the 'Chrysophyceae' algal communities, but the 'Endoderma' belt grew on both chalk and seawalls (Tittley & Shaw, 1980, Figure 11; Fowler & Tittley, 1993). Titlley (1988) reported that *Pseudendoclonium submarinum* grew on chalk and hard chalk, sea walls, limestone, hard rock and flint in crevices and cracks. Nevertheless, coastal defence works also resulted in loss of caves or cut caves off from the influence of the sea (Fowler & Tittley, 1993).

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'**), in this case, loss of caves themselves. 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

Soft rock, such as chalk, is liable to split and wave action and frost can result in loss of the surface of the rock, and localised landslides. However, this would free up new substratum for colonization, and the biotope would probably recover quickly. It is unlikely that chalk cliffs would be replaced by sedimentary substrata. But the replacement of soft chalk with man-made structures, e.g. of concrete or hard rock has resulted in the loss of the chalk cliff algal communities (Tittley *et al*., 1988; Fowler & Tittley, 1993). The resultant sea walls did not support the 'Chrysophyceae' algal communities, but the 'Endoderma' belt grew on both chalk and sea walls (Tittley & Shaw, 1980, Figure 11; Fowler & Tittley, 1993). Anand (1937b) reported that the 'Endoderma' belt was replaced on embankments by a dark coloured band of the blue-green alga *Pleurocapsa entophysaloides*, the Chlorophyte*Trebouxia humicola* and *Pseudendoclonium submarinum (as Endoderma perforans).* Titlley (1988) reported that *Pseudendoclonium submarinum* grew on chalk and hard chalk, sea walls, limestone, hard rock and flint in crevices and cracks. Humm & Belt (1975) also recorded *Pseudendoclonium submarinum* from artificial substrata such as timber and bridge pilings.

Sensitivity assessment. Therefore, the 'Endoderma' belt that characterizes this biotope could grow on a range of soft or hard rock substrata. However, a change to sedimentary substrata, however unlikely, would result in the permanent loss of the biotope. Resistance is assessed as **None**, resilience as **Very low** (as it is a permanent change) and sensitivity as **High**.

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

It is unlikely that chalk would be replaced by sediment in the littoral fringe or supralittoral. Therefore, this pressure is **Not relevant**. However, change in substratum type is address above.

Habitat structure changes - removal of substratum (extraction)	None Q: Low A: NR C: NR	High Q: Medium A: Medium C: Medium	Medium Q: Low A: Low C: Low

Extraction of sediment, as described under this pressure, is not relevant in rock habitats. However, soft rocks could suffer extraction due to tunnelling, mining or construction. Therefore, removal of chalk from the cliff would remove the surface 'Chrysophyceae' and 'Endoderma' belts, resulting in loss of the biotope. Resistance would, therefore, be **None**. But if the existing substratum (chalk) remains in the same habitat (upper littoral fringe to supralittoral) then the biotope would recover rapidly and resilience is probably **High**, therefore, sensitivity to extraction is probably **Medium**.

	Resistance	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Low Q: Low A: NR C: NR	High Q: Low A: NR C: NR	Low Q: Low A: Low C: Low

The *Pseudendoclonium submarinum* ('Endoderma') belt exists as a thin coating of the rock. These algal communities are likely to be removed as a result of any abrasion, e.g. from vessel grounding or recreational access and trampling, especially where the friable rock surface is removed. Therefore, resistance is probably **Low** (depending on the scale of the impact). However, recovery is likely to be rapid if suitable substratum remains so that resilience is probably **High** and sensitivity is probably **Low**.

Penetration or disturbance of the substratum subsurface	Low Q: Low A: NR C: NR	High Q: Low A: NR C: NR	Low Q: Low A: Low C: Low

Penetration by mobile fishing gear is unlikely to occur in caves. or on vertical chalk cliffs. However, soft rock, by definition, can be damaged by other penetrative activities, for example during construction. The *Pseudendoclonium submarinum* (Endoderma) belt exists as a thin coating of the rock. These algal communities are likely to be removed as a result of any abrasion or penetration, especially where the friable rock surface is removed. Therefore, resistance is probably **Low** (depending on the scale of the impact). However, recovery is likely to be rapid if suitable substratum remains so that resilience is probably **High** and sensitivity is probably **Low**.

Changes in suspended solids (water clarity)	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

The upper littoral fringe or supralittoral are rarely inundated. It is, therefore, unlikely to be exposed to changes in water clarity due to changes in suspended sediment.

Smothering and siltation rate changes (light)	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

Smothering could occur as a result of rainwater runoff of silt and soil from the tops of the cliffs. However, the slope of the cliff would preclude the build up of significant deposits (except on crevices and pits) sufficient to block the algal communities access to sunlight. Similarly, smothering of vertical walls and ceilings of caves is unlikely. Therefore, the factor is probably **Not relevant** at the level of the benchmark. Smothering by impermeable materials or by other hard construction materials, however, would result in loss of the biotope (see physical loss above).

Smothering and siltation rate changes (heavy)	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

Smothering could occur as a result of rainwater runoff of silt and soil from the tops of the cliffs. However, the slope of the cliff would preclude the build up of significant deposits (except on crevices and pits) sufficient to block the algal communities access to sunlight. Similarly, smothering of vertical walls and ceilings of caves is unlikely. Therefore, the factor is probably **Not relevant** at the level of the benchmark. Smothering by impermeable materials or by other hard construction materials, however, would result in loss of the biotope (see physical loss above).

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

Not assessed. Litter is unlikely to accumulate on vertical or steep slopes or cave ceilings.

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

No evidence was found.

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

Not relevant. The biotope is rarely underwater and microalgae are not known to respond to noise.

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

Anand (1937b&c) reported that the *Pseudendoclonium submarinum* (as *Endoderma perforans*) was favoured within the Chrysophyceae belt, during diffuse light or short duration in winter. Incident light in tunnels was considerably less than on cliff faces (Anand, 1937c) and the 'Endoderma' belt was more extensive in tunnels than on cliff faces Anand (1937b&c) noted that the Endoderma belt became very prominent and extended to the roof in well-illuminated caves, while the 'Chrysophyceae' belt was restricted to the entrance. The Chrysophyceae-Endoderma-Lyngbya community was also restricted to the entrance of caves but did not exhibit its usual brown colour, as it was green due to the growth of *Pseudendoclonium submarinum.* Therefore, an increase in shading may benefit the 'Endoderma' belt, depending on intensity, as a complete lack of light would be detrimental for all algae. Resistance to shading is probably **Medium.** Hence, resilience is probably **High** and the sensitivity to change in light is probably **Low**.

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

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

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

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

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

Not relevant. Microalgae respond to light intensity but are unlikely to respond to 'visual' cues.

Biological Pressures

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

No evidence was found to suggest microalgae that characterize the green algal mats in this biotope were subject to translocation, nor that they were subject to genetic modification or hybridization with other similar species. Several species of Chlorophyceae may be cultured as a food source or for research but no evidence was found to suggest that genetically modified or laboratory stocks were released into the wild.

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

No evidence was found.

Introduction of microbial pathogens	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

Viruses are thought to play a part in the control of phytoplankton populations (Brussaard, 2004). However, no evidence specific to these chalk cliff or cave communities was found.

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

The microalgal communities characteristic of this biotope are unlikely to be targetted by any commercial or recreational fishery or harvest.

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

Incidental removal of the 'Endoderma' belt would probably remove the entire belt rather than specific characteristic species. Where present, mobile invertebrate fauna are probably not entirely dependent on the 'belt' for food or habitat and would forage elsewhere. However, soft-rock and cave communities are unlikely to be targetted by any commercial or recreational fishery or harvest. Accidental physical disturbance due to access (e.g. trampling) or grounding is examined under abrasion above.

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