Chrysophyceae and Haptophyceae on vertical upper littoral fringe soft rock

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

Dr Harvey Tyler-Walters

2016-01-29

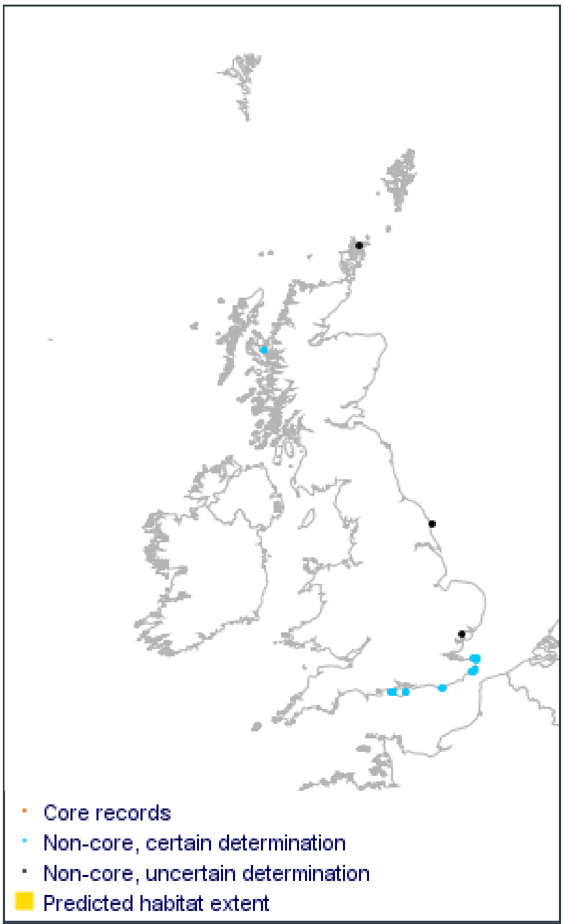
A report from:
The Marine Life Information Network, Marine Biological Association of the United Kingdom.

Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [https://www.marlin.ac.uk/habitats/detail/121]. All terms and the MarESA methodology are outlined on the website (https://www.marlin.ac.uk)

This review can be cited as:
Tyler-Walters, H., 2016. Chrysophyceae and Haptophyceae on vertical upper littoral fringe soft rock. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom.
DOI https://dx.doi.org/10.17031/marlinhab.121.1

The information (TEXT ONLY) provided by the Marine Life Information Network (MarLIN) is licensed under a Creative Commons Attribution-Non-Commercial-Share Alike 2.0 UK: England & Wales License. Note that images and other media featured on this page are each governed by their own terms and conditions and they may or may not be available for reuse. Permissions beyond the scope of this license are available here. Based on a work at www.marlin.ac.uk

Base of vertical chalk cliff showing green cover of Chrysophyceae.
Photographer: Tim Hill
Copyright: Joint Nature Conservation Committee (JNCC)



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

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

Summary

UK and Ireland classification

EUNIS 2008	A1.441	Chrysophyceae and Haptophyceae on vertical upper littoral fringe soft rock
JNCC 2015	LR.FLR.CvOv.ChrHap	Chrysophyceae and Haptophyceae on vertical upper littoral fringe soft rock
JNCC 2004	LR.FLR.CvOv.ChrHap	Chrysophyceae and Haptophyceae on vertical upper littoral fringe soft rock
1997 Biotope	LR.L.Chr	Chrysophyceae on vertical upper littoral fringe soft rock

Description

Chrysophyceae communities form orange, brownish or blackish gelatinous bands at high tide and supralittoral levels on open cliff faces and in caves and tunnels of soft rock. Open cliff-faces and entrances to chalk caves and tunnels at lower supralittoral levels bear a dark brown band comprising an assemblage dominated by *Apistonema carterae*. During summer this gelatinous growth dries and often peels off. The filamentous green alga *Epicladia perforans* is often associated with *Apistonema*, forming a green layer beneath the upper layer of *Apistonema*. *Entodesmus maritima* and *Thallochrysis litoralis* are commonly associated with *Apistonema*. Associated with this splash zone algal community is an assemblage of animals of terrestrial origin, with red mites, insects and centipedes commonly found. These species descend into the community as the tide falls and retreat as the tide rises. The most common truly marine species is the small winkle *Melarhaphe neritoides*. (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

Depth range

Upper shore

Additional information

This review is primarily based on detailed studies of the supralittoral algal flora by Anand, (1937a,b, &c) and Tittley & Shaw (1980), to which the reader should refer for further information. Please note, a recent molecular taxonomic study by Andersen *et al.* (2014) has synonymized *Gloeochrysis litoralis, Gloeochrysis maritima, Apistonema carteri*, *Thallochrysis litoralis*, and *Ruttnera litoralis* with *Chrysotila stipitata* (Anand 1936/1937).

Listed By

- none -

Further information sources

Search on:

G G G JNCC

Habitat review

Ecology

Ecological and functional relationships

The upper littoral fringe and supralittoral lie above high water springs, and is influenced by wave wash, splash and spray. The mobile fauna will vary with the tide and wave exposure with marine intertidal species further up the shore at high tide and mobile species of terrestrial origin foraging down the shore as the tide recedes only to return to the top of the shore as the tide returns. Other species of terrestrial origin, notably mites (acarids), and some spring tails (Collumbola) seek refuge is cracks and crevices at high tide.

- Chrysophyceae, Haptophyceae, blue-green algae (Cyanobacteria) and fine filamentous green algae (Chlorophycota) are primary producers, converting sunlight and simple inorganics to biomass.
- Grazers and browsers feed on unicellular green algae (Chrysophyceae), lichens, and fine filamentous green algae, e.g. the sea slater *Ligia oceanica*, the bristletail *Petrobius maritimus*, the small periwinkle *Melarhaphne neritoides* and some acarid mites (Nicholls, 1931; Joosse, 1976; Roth & Brown, 1976; Pugh & King, 1988; Carefoot & Taylor, 1995; Bücking, 1998).
- Detritus may accumulate in pits or crevices and is fed on by detritivores such as acarid mites.
- Predators include mites (acarids), centipedes of terrestrial or intertidal origin (e.g. *Strigamia maritima*, which may take isopods, amphipods and periwinkles), and terrestrial or maritime spiders (Roth & Brown, 1976; Pugh & King, 1988).
- The sea slater (*Ligia oceanica*) may also act as a scavenger (Nicholls, 1931).

Several species are probably more active at night (e.g. *Ligia oceanica*) to avoid predation by foraging birds. Anand (1937a,b&c) originally described the 'Chrysophyceae' communities of soft chalk cliffs but several species (e.g. *Apistonema* sp. and *Chrysotila* sp.) are now described under Haptophyceae (Fowler & Tittley, 1993; van den Hoek *et al.*, 1995), however, the term 'Chrysophyceae' mat or belt is still used.

Seasonal and longer term change

Tittley & Shaw (1980) suggested that *Apistonema* sp. changed little with the season. In winter, the mucilaginous 'Chrysophyceae' mat may be punctuated by light brown or white patches caused by frost. *Chrysotila stipitata* (Haptophyceae) community develops in winter but in summer may dry and peel off, being restricted to shaded, moist locations. The primary 'Chrysophyceae' community, dominated by *Apistonema carterae* is best developed in winter and present all year round. Prolonged exposure to sunlight and high temperatures in summer when the seas are calm (low humidity) may result in drying of the mat, which cracks and curls up (Anand, 1937b; Plate IV B). In winter, the mucilaginous mat may be covered by the filamentous growth of *Ulothrix* sp., and in spring and summer the mat may support numerous species of diatom. Cyanobacteria (e.g. *Calothrix* sp. and *Schizothrix fritschii*) are more common in summer. The *Rivularia atra* belt (see habitat complexity) is best developed in winter but dies back in summer. The growth of the fine green filamentous algae *Pseudendoclonium submarinum* (previously described by Anand as *Endoderma perforans*) is favoured in winter (Anand, 1937b; Tittley & Shaw, 1980; Burrows, 1991). No information concerning seasonal changes in the associated fauna was found.

Habitat structure and complexity

This biotope occurs in the upper littoral fringe and supralittoral of soft vertical rock cliffs, above the high water of springs tides, and replaces the *Verrucaria maura* communities typically found on hard rock substrata. Supralittoral algal communities show a distinct zonation pattern (Anand 1937a,b,&c; Magne, 1974; Tittley & Shaw, 1980). The height of the supralittoral zone and, hence, the height of each individual algal band (or zone) is dependent on moisture and humidity. Moisture or humidity are dependent on the height reached by wave wash, splash and spray and, therefore, on the degree of wave exposure, the porosity of the rock, and the drying forces of wind and sunlight and hence, the north or south aspect of the cliff face. For example, on wave exposed North Atlantic headlands the supralittoral may reach 50-60 ft (ca 15-18m) above mean high water springs tides (MHWS) but only reach 4-5 ft (ca 1-1.5m) above on sheltered shores (Lewis, 1964). The surface of the soft rock provides complexity to the habitat in the form of pits or crevices that retain moisture and may be punctuated by tunnels and caves. Chrysophyceae and Haptophyceae are single celled (unicellular) microalgae more usually found in planktonic communities. The Chrysophyceae and Haptophyceae found in soft rock communities form a thallus of algal cells bound by mucilage or filaments of mucilage (Anand, 1937a; van den Hoek *et al.*, 1995). Anand (1937a,b&c) described five main communities of Chrysophyceae, Haptophyceae and Cyanobacteria associated with the 'Chrysophyceae' mat.

Zonation (down the shore from the yellow and grey lichen belt)

- An upper belt (45 cm or more high) of the fine green filamentous algae *Pseudendoclonium submarinum* (previously described by Anand as *Endoderma perforans*), filaments of which penetrate the loose rock and give the rock face a green hue. The *Pseudendoclonium submarinum* belt may reach 8-10 m above high water, more in caves and recesses where the waves break and spray reaches higher.
- A lower belt of 'Chrysophyceae' communities, forming an orange, light or dark brownish mucilaginous mat. The mucilaginous mat grows over a layer of *Pseudendoclonium submarinum* that grows endophytically within the 'Chrysophyceae' mat, from which it may protrude. Alternating layers of green algae within the brown Chrysophyceae may form, depending on the season.
- The 'Chrysophyceae' belt is dominated by *Apistonema carterae*, commonly with *Thallochrysis litoralis* and *Gloeochrysis maritima*. *Chrysotila stipitata* (Haptophyceae) may form a separate 'Chrysophyceae' community, especially in the winter months.
- Several species of blue-green algae (Cyanobacteria) live endophytically within the 'Chrysophyceae' mat forming layers of black or dark brown growth within the mucilaginous mat, e.g. the *Calothrix* sp. community. *Schizothrix fritschii* (Cyanobacteria), however, may form erect branched bundles of a yellowish or green olive colour on the surface of the mat.
- A band of *Rivularia atra* (Cyanobacteria) may occur between the bottom of the 'Chrysophyceae' belt and the top of the *Ulva* sp. zone (Anand, 1937a,b&c; Tittley & Shaw, 1980; Burrows, 1991).
- In the winter months, the mucilaginous mat may be covered by the fine, felt like growth of the green algae *Ulothrix* sp.
- The lower limit of this biotope is delimited by a band dominated by *Ulva* sp. (see MLR.Eph).

Caves

The 'Chrysophyceae' belt is found near the entrance but its vertical extent is increased and it may extend for 6-8 m from the floor in well illuminated caves. The dominant species vary with light intensity and hence, distance into the cave (Anand, 1937b). *Pseudendoclonium submarinum* (described as *Endoderma perforans*) penetrates the surface of the mucilaginous mat giving it a green colour. *Pseudendoclonium submarinum* becomes more prominent in vertical extent in caves than on open cliffs. Anand (1937b) describes three algal communities specific to soft rock caves.

Productivity

The Chrysophyceae, Haptophyceae, the associated Chlorophycota and Cyanobacteria provide primary production within this biotope. However, no further information was found.

Recruitment processes

Chrysophyceae and Haptophyceae reproduce predominantly by asexual reproduction. Flagellate zoospores may also be produced. The Haptophyta *Chrysotlia lamellosa* is predominately benthic but the motile flagellate part of the life-cycle is an abundant member of the phytoplankton, previously described as *Isochrysis maritima*. The fine, filamentous green algae found in this biotope produce motile zoospores and swarmers. While Cyanobacteria do not form flagellate cells, they are ubiquitous. Hence, the algae species within this biotope have a high potential for dispersal, depending on local currents.

Therefore, it is likely that recolonization of soft rock cliffs would be relatively rapid, probably occurring within a year. Tittley & Shaw (1980) noted that *Apistonema* sp. was replaced by *Entophysalis* sp. (Cyanobacteria) on sea walls and that hard, impervious rock substrata supported different algae communities to those of soft, porous rock substrata. This was probably dependent on the moisture retained by the porous rock surface, e.g. chalk and the ability of algal spores to settle and stick to rough rather than smooth surfaces (Tittley & Shaw, 1980).

Time for community to reach maturity

Little information was found. The 'Chrysophyceae' communities develop in winter, with Cyanobacteria developing in spring and summer, suggesting a seasonal cycle. Therefore, it is likely that the community would reach maturity within a year.

Additional information

With the exception of the studies indicated above, the ecology of soft rock algal communities has received little attention.

Preferences & Distribution

Habitat preferences

Depth Range	Upper shore
Water clarity preferences	Not relevant
Limiting Nutrients	Nitrogen (nitrates), Phosphorus (phosphates), Silicon (silicates)
Salinity preferences	Full (30-40 psu), Variable (18-40 psu)
Physiographic preferences	
Biological zone preferences	Upper littoral fringe

Substratum/habitat preferences	Caves, Chalk
Tidal strength preferences	
Wave exposure preferences	Moderately exposed
Other preferences	Soft porous rock

Additional Information

Soft rocks such as sandstone, limestone (or brick) but especially chalk support diverse algal communities characteristic of this biotope. However, on smooth, impermeable rock surfaces (including artificial substrata such as concrete) the Chrysophyceae and Haptophyceae were replaced by Cyanobacteria (Entophysalis sp.) (Tittley & Shaw, 1980; Fowler & Tittley, 1993).

Several members of this community, especially the fine filamentous algae, Chrysophyceae and Haptophyceae are difficult to identify. Therefore, this biotope and its component species may be under recorded in the British Isles. However, the distribution of this biotope is limited to suitable environmental conditions on suitable rock surfaces (e.g. chalk cliffs) many of which have been affected by the construction of sea defences resulting in loss of this biotope in parts of the UK (see importance; Fowler & Tittley, 1993).

Species composition

Species found especially in this biotope

- *Apistonema carterae*
- *Chrysotila lamellosa*
- *Chrysotila stipitata*
- *Ectocarpus sp.*
- *Entocladia viridis*
- *Entodesmis litoralis*
- *Entodesmis maritima*
- *Gleochrysis maritima*
- *Kuetzingiella holmesii*
- *Petalonia filiformis*
- *Pleurocladia lacustris*
- *Praisnocladus lubricus*
- *Pringsheimiella scutata*
- *Pseudendoclonium submarinum*
- *Thallochrysis litoralis*
- *Trebouxia humicola*
- *Ulvella lens*

Rare or scarce species associated with this biotope

-

Additional information

The composition of the 'Chrysophyceae' communities and associated species were described in detail by Anand (1937a,b,&c) and in subsequent surveys by Tittley & Shaw (1980) and Tittley (1985; 1988). Anand (1937b) described two main Chrysophyceae communities and three associated Cyanobacteria communities in addition to the *Pseudendoclonium submarinum* community. In addition, Anand (1937a) recorded two species new to the British Isles and several rare species (see Fowler & Tittley, 1993).

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

This biotope is characterized by the presence of the mucilaginous mat of Chrysophyceae and Haptophyceae, dominated by *Apistonema carterae*, growing in association with *Pseudendoclonium submarinum* (previously described by Anand (1936, 1937a) as *Endoderma perforans*). The composition of the 'Chrysophyceae and Haptophyceae' communities varies with season, moisture and in caves or tunnels. The arthropod community (red mites, insects, centipedes, and spiders) are mobile species that are found within the supralittoral and are not dependent on this biotope. Therefore, the 'Chrysophyceae and Haptophyceae' communities as a whole have been used to indicate the sensitivity of the biotope and no indicative species were chosen. However, in undertaking this assessment of sensitivity, an account was taken of knowledge of the biology of all characterizing species in the biotope.

Resilience and recovery rates of habitat

Chrysophyceae and Haptophyceae reproduce predominantly by asexual reproduction. Flagellate zoospores may also be produced and 'swarmers' have been identified in *Chrysotila* spp. (Green & Parke, 1975). Several members Chrysophyceae and Haptophyceae of the exhibit both a motile flagellated form and a thalloid or tissue-like phase, e.g. *Thallocrysis* spp (Van den Hoek *et al.*, 1995). The Haptophyta *Chrysotlia lamellosa* is predominately benthic but the motile flagellate part of the life-cycle is an abundant member of the phytoplankton, previously described as *Isochrysis maritima* (Van den Hoek *et al.*, 1995).

The fine, filamentous green algae found in this biotope produce motile zoospores and swarmers. While Cyanobacteria do not form flagellate cells, they are ubiquitous. Hence, the algae species within this biotope have a high potential for dispersal, depending on local currents. Tittley & Shaw (1980) noted that *Apistonema* sp. was replaced by *Entophysalis* sp. (Cyanobacteria) on sea walls and that hard, impervious rock substrata supported different algae communities to those of soft, porous rock substrata. This was probably dependent on the moisture retained by the porous rock surface, e.g. chalk and the ability of algal spores to settle and stick to rough rather than smooth surfaces (Tittley & Shaw, 1980).

The characteristic members of the flora produce swarmers or can occur as motile, flagellate algae in the phytoplankton. Therefore, it is likely that recolonization of soft rock cliffs would be relatively rapid, probably occurring within a year. The 'Chrysophyceae' communities develop in winter, with Cyanobacteria developing in spring and summer, suggesting a seasonal cycle. Therefore, it is likely that the community would reach maturity within a year and resilience is assessed as **High**, even where the community is removed.

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	Low Q: High A: High C: High	High Q: Medium A: Medium C: Medium	Low Q: Medium A: Medium C: Medium

Anand (1937c) examined the range of temperatures experienced by chalk cliff algal communities. The *Pseudendoclonium submarinum* 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. The mucilaginous Chrysophyceae belt was consistently lower in temperature than the air, was least affected by changes in air temperature and showed no marked variation over several hours. Anand (1937c) concluded that its water content and retention acted as a buffer against temperature change. Curiously, in contrast, the *Ulva* sp. and *Fucus* sp. belts of the lower shore showed a much greater range of temperatures, especially in bright sunlight. However, Anand (1937b&c) also noted that prolonged exposure to high temperatures during summer in desiccating conditions resulted in death, cracking and peeling off of the 'Chrysophyceae' belt. The mat was seldom seen to crack in areas sheltered from direct sunlight and/or wind.

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, resulting in loss of the proportion of the population depending on its shelter and aspect. Hence, a resistance of **Low** has been recorded. Once prior conditions return, recovery is likely to be rapid and resilience is probably **High**. Hence, sensitivity is likely to be **Low**.

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

Anand (1937b&c) reported that light brown or white patches appeared in the 'Chrysophyceae' mat during winter due to frost. 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. Since the Chrysophyceae communities are best developed in winter and the associated Cyanobacteria communities develop in spring and summer the biotope as a whole may benefit from a reduction in average summer temperatures. Therefore, **resistance** is probably **High,** so that resilience is also **High** and **Not sensitive** has been recorded.

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

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. 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. However, in the 'Chrysophyceae' belt the salt concentration may be approximately three times that of seawater (Anand, 1937c). Therefore, since soft rock algal communities are also likely to be exposed to freshwater in the form of rain, 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 Q: High A: High C: High	High Q: Medium A: Medium C: Medium	Not sensitive Q: Medium A: Medium C: Medium

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. 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. However, in the 'Chrysophyceae' belt the salt concentration may be approximately three times that of seawater (Anand, 1937c). Therefore, since soft rock algal communities are also likely to be exposed to freshwater in the form of rain, this biotope is probably resistant to changes in salinity comparable to the benchmark (i.e. full to reduced). Therefore, a resistance of **High** is suggested, so that resilience is also **High** and **Not sensitive** is recorded.

Water flow (tidal current) changes (local)	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

The upper littoral fringe and supralittoral are rarely if ever inundated. Therefore, the biotope is unlikely to be affected by water flow as described by the benchmark. Runoff due to heavy rainfall is possible but is outside the scope of the pressure. Therefore, the pressure is **Not relevant**.

Emergence regime changes	Low Q: High A: Medium C: Medium	High Q: Medium A: Medium C: Medium	Low Q: Medium 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 drought 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 belts 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.

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.

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 and a resistance of **Low** has been recorded at the benchmark level. 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. Similarly, Lewis (1964) noted that the supralittoral could reach 50-60 ft above mean high water springs on wave exposed North Atlantic headlands. 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 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.

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 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 rock algal 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 rock algal communities are intolerant of synthetic chemicals, in particular, herbicides that may be contained in runoff (during heavy rains) from adjacent agricultural land.

Radionuclide contamination	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.

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

Nutrient enrichment	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	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. and even *Pseudendoclonium submarinum* may overgrow the 'Chrysophyceae' belt, 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	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

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. and even *Pseudendoclonium submarinum* may overgrow the 'Chrysophyceae' belt, 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). The resultant sea walls do not support the 'Chrysophyceae' algal communities, although limestone and brick structures support similar communities but with a reduced range of chalk species and communities (Tittley & Shaw, 1980; 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.*, 1998). 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.

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

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.

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). The resultant sea walls do not support the 'Chrysophyceae' algal communities, although limestone and brick structures support similar communities but with a reduced range of chalk species and communities (Tittley & Shaw, 1980; 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.*, 1998). 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.

Sensitivity assessment. Therefore, the 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 soft 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 Haptophyceae belt, 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.

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

The 'Chrysophyceae' mat is very thin (a few millimetres) and the *Pseudendoclonium submarinum* 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: Medium A: Medium C: Medium	Low Q: Low A: Low C: Low

Penetration by mobile fishing gear is unlikely to occur on vertical chalk cliffs. However, soft rock, by definition, can be damaged by other penetrative activities, for example during construction. The 'Chrysophyceae' mat is very thin (a few millimetres) and the *Pseudendoclonium submarinum* 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. 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. 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.

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

An increase in artificial light might be beneficial but shading is likely to result in loss of the biotope. Anand (1937b&c) reported that the Chrysophyceae belt was restricted to the entrance and mouth of caves and out-competed in tunnels. In the two caves examined, the Chrysophyceae belt was restricted to the 9m from the cave mouth where light intensity was reduced to 10% of incident light. In caves where light could not penetrate, the Chrysophyceae belt was replaced in shaded areas. Resistance to shading is probably **Low**. However, the Chrysophyceae belt would probably recover rapidly once the shading activity is removed, and resilience is probably **High**. Therefore, 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 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 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	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 to suggest that the Chrysophyceae and Haptophyceae 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 Chrysophyceae and Haptophyceae 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	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.

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

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

Soft-rock algal communities 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 Chrysophyceae and Haptophyceae 'belt' would probably remove the entire belt rather than specific characteristic species. The Cyanobacteria probably depend on the mucilaginous 'belt' for substratum but are otherwise not closely associated with any other species. Similarly, the mobile invertebrate fauna are probably not entirely dependent on the 'belt' for food or habitat and would forage elsewhere.

However, soft-rock 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.

Bibliography

Anand, P.L., 1937a. A taxonomic study of the algae of British Chalk-cliffs. *Journal of Botany*, **75** (Supplement II), 1-51.

Anand, P.L., 1937b. An ecological study of the algae of the British chalk cliffs. Part I. *Journal of Ecology*, **25**, 153-188.

Anand, P.L., 1937c. An ecological study of the algae of the British chalk cliffs. Part II. *Journal of Ecology*, **25**, 344-367.

Andersen, R.A., Kim, J.I., Tittley, I. & Yoon, H.S., 2014. A re-investigation of *Chrysotila* (Prymnesiophyceae) using material collected from the type locality. *Phycologia*, **53** (5), 463-473.

Anonymous, 1999e. Littoral and sublittoral chalk. http://www.ukbap.org.uk/ukplans.aspx?id=31, 2001-09-26

Beaumont, A.R. & Newman, P.B., 1986. Low levels of tributyl tin reduce growth of marine micro-algae. *Marine Pollution Bulletin*, **17**, 457-461.

Brussaard, C.P.D., 2004. Viral Control of Phytoplankton Populations — a Review. *Journal of Eukaryotic Microbiology*, **51**(2), 125-138.

Bryan, G.W. & Gibbs, P.E., 1991. Impact of low concentrations of tributyltin (TBT) on marine organisms: a review. In: *Metal ecotoxicology: concepts and applications* (ed. M.C. Newman & A.W. McIntosh), pp. 323-361. Boston: Lewis Publishers Inc.

Bücking, J., 1998. Investigations on the feeding habits of the rocky shore mite *Hyadesia fusca* (Acari: Astigmata: Hyadesiidae): diet range, food preference, food quality, and the implications for distribution patterns. *Helgolander Meersuntersuchungen*, **52**, 159-177.

Burrows, E.M., 1991. *Seaweeds of the British Isles. Volume 2. Chlorophyta.* London: British Museum (Natural History).

Carefoot, T.H. & Taylor, B.E., 1995. *Ligia*: a prototypal terrestrial isopod. In *Terrestrial isopod biology* (ed. M.A. Alikhan), pp. 47-60. Rotterdam: A.A. Balkema. [Crustacean Issues 9.]

Cheng, L. (ed.), 1976. *Marine insects.* Amsterdam: North-Holland Publishing Company.

Cole, S., Codling, I.D., Parr, W. & Zabel, T., 1999. Guidelines for managing water quality impacts within UK European Marine sites. *Natura 2000 report prepared for the UK Marine SACs Project.* 441 pp., Swindon: Water Research Council on behalf of EN, SNH, CCW, JNCC, SAMS and EHS. [UK Marine SACs Project.], http://www.ukmarinesac.org.uk/

Connor, D.W., Brazier, D.P., Hill, T.O., & Northen, K.O., 1997b. Marine biotope classification for Britain and Ireland. Vol. 1. Littoral biotopes. *Joint Nature Conservation Committee, Peterborough, JNCC Report* no. 229, Version 97.06., *Joint Nature Conservation Committee, Peterborough, JNCC* Report No. 230, Version 97.06.

Davies, C.E. & Moss, D., 1998. European Union Nature Information System (EUNIS) Habitat Classification. *Report to European Topic Centre on Nature Conservation from the Institute of Terrestrial Ecology, Monks Wood, Cambridgeshire.* [Final draft with further revisions to marine habitats.], Brussels: European Environment Agency.

Fletcher, R.L., 1987. *Seaweeds of the British Isles* vol. 3. *Fucophyceae (Phaeophyceae) Part 1*. London: British Museum (Natural History).

Fowler, S.L. & Tittley, I., 1993. The marine nature conservation importance of British coastal chalk cliff habitats. *English Nature Research Reports, no. 32.*

Green, J.C. & Parke, M., 1975. New observations upon members of the genus *Chrysotila* Anand, with remarks upon their relationships within the Haptophyceae. *Journal of the Marine Biological Association of the United Kingdom*, **55**, 109-121.

JNCC, 2015. The Marine Habitat Classification for Britain and Ireland Version 15.03. (20/05/2015). Available from https://mhc.jncc.gov.uk/

JNCC (Joint Nature Conservation Committee), 1999. *Marine Environment Resource Mapping And Information Database (MERMAID): Marine Nature Conservation Review Survey Database.* [on-line] http://www.jncc.gov.uk/mermaid

Joosse, E.N.G., 1976. Littoral apterygotes (Collembola and Thysanura). In *Marine insects* (ed. L. Cheng), pp. 151-186. Amsterdam: North-Holland Publishing Company.

Lewis, J.R., 1964. *The Ecology of Rocky Shores.* London: English Universities Press.

Magne, F., 1974. Peuplement d'un substrat calcaire dans la zone intercotidale. *Bulletin. Société phycologique de France. Paris*, **19**, 121-128.

Nicholls, A.G., 1931. Studies on *Ligia oceanica*. Part II. The process of feeding, digestion and absorption, with a description of the structure of the foregut. *Journal of the Marine Biological Association of the United Kingdom*, **17**, 675-705.

Pugh, P.J.A. & King, P.E., 1988. Acari of the British Isles. *Journal of Natural History*, **22**, 107-122.

Roth, V.D. & Brown, W.L., 1976. Other intertidal air-breathing arthropods. In *Marine insects* (ed. L. Cheng), pp. 119-150.

Tittley, I. & Shaw, K.M., 1980. Numerical and field methods in the study of the marine flora of chalk cliffs. In *The shore environment*, vol. 1: *methods* (ed. J.H. Price, D.E.G. Irvine & W.F. Farnham), pp. 213-240. London & New York: Academic Press. [Systematics Association Special Volume, no. 17(a).]

Tittley, I., 1985. Chalk cliff algal communities of Kent and Sussex, Southeast England. *Nature Conservancy Council, Contract Reports*, no. 200., Peterborough: Nature Conservancy Council.

Tittley, I., 1988. Chalk cliff algal communities: 2. Outside south eastern England. *Nature Conservancy Council, Contract Reports*, no. 878., London: British Museum (Natural History).

Tittley, I., Spurrier, C.J.H., Chimonides, P.J., George, J.D., Moore, J.A., Evans, N.J. & Muir, A.I., 1998. Survey of chalk cave, cliff, intertidal and subtidal reef biotopes in the Thanet coast cSAC. *Report to English Nature.*, London: Natural History Museum.

Van den Hoek, C., Mann, D.G. & Jahns, H.M., 1995. *Algae: an introduction to phycology*: Cambridge University Press.