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Polyides rotunda, *Ahnfeltia plicata* and *Chondrus crispus* on sand-covered infralittoral rock

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

Dr Heidi Tillin & Will Rayment

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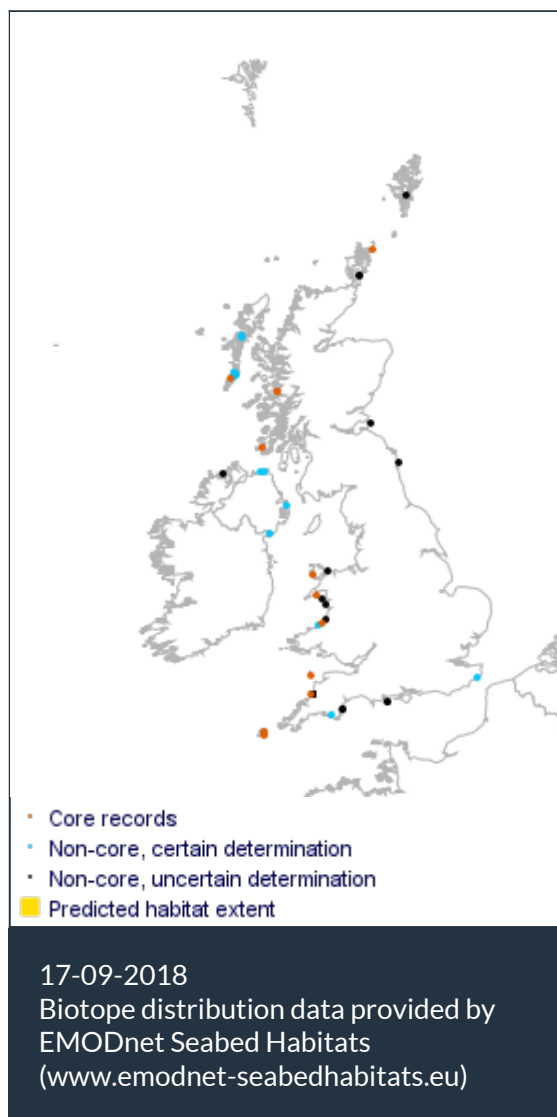
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Researched by Dr Heidi Tillin & Will Rayment

Refereed by This information is not refereed.

Summary

☰ UK and Ireland classification

EUNIS 2008	A3.127	<i>Polyides rotundus</i> , <i>Ahnfeltia plicata</i> and <i>Chondrus crispus</i> on sand-covered infralittoral rock
JNCC 2015	IR.HIR.KSed.ProtAhn	<i>Polyides rotunda</i> , <i>Ahnfeltia plicata</i> and <i>Chondrus crispus</i> on sand-covered infralittoral rock
JNCC 2004	IR.HIR.KSed.ProtAhn	<i>Polyides rotundus</i> , <i>Ahnfeltia plicata</i> and <i>Chondrus crispus</i> on sand-covered infralittoral rock
1997 Biotope	IR.MIR.SedK.PoIAhn	<i>Polyides rotundus</i> , <i>Ahnfeltia plicata</i> and <i>Chondrus crispus</i> on sand-covered infralittoral rock

🔍 Description

Low-lying rock surrounded by mobile sand and often subject to burying by the sand, with a turf of resilient red seaweeds *Chondrus crispus*, *Polyides rotunda* and *Ahnfeltia plicata* typically protruding

through the sand on the upper surfaces of the rock. Other scour-tolerant seaweeds include *Rhodomela confervoides*, *Phyllophora pseudoceranoides*, *Phyllophora crispa*, *Furcellaria lumbricalis*, *Gracilaria gracilis*, *Ceramium rubrum*, *Plocamium cartilagineum*, *Heterosiphonia plumosa*, *Cryptopleura ramosa* and *Dilsea carnosa*. Coralline crusts typically cover the rock, while scattered individuals of the brown seaweeds *Halidrys siliquosa*, *Cladostephus spongiosus*, *Dictyota dichotoma* and *Saccharina latissima* can be present. The large anthozoan *Urticina felina* can occur in this biotope but there are few other conspicuous animals (Connor et al., 2004: [JNCC](#)).

↓ Depth range

5-10 m

Additional information

-

✓ Listed By

- none -

Further information sources

Search on:



Habitat review

🔄 Ecology

Ecological and functional relationships

- The principal feature of the MIR.PolAhn biotope is an algal turf dominated by perennial species tolerant of soft or friable rock and overlying sand. They are therefore released from the competition of less tolerant algae, which typically limits them in less specialized conditions. The characterizing species include *Ahnfeltia plicata*, *Furcellaria lumbricalis*, *Polyides rotunda* and *Chondrus crispus*. (Lewis, 1964.)
- Other algae which contribute to the mixed turf include *Cryptopleura ramosa*, *Dilsea carnosa*, *Halidrys siliquosa*, *Phyllophora crispa*, *Phyllophora pseudoceranoides* and *Dictyota dichotoma*.
- The density of the algal turf discourages a rock-attached fauna (Lewis, 1964). *Chondrus crispus* for example is highly resistant to intense physical and herbivore induced disturbance ensuring a dense canopy which largely excludes recruitment of fauna and other algae (Chopin & Wagey, 1999).
- Fast growing ephemeral algae, e.g. filamentous green *Cladophora* sp., grow epiphytically and colonize gaps in the perennial turf as and when they occur (Barnes & Hughes, 1992).
- Encrusting coralline algae grow epiphytically on the turf forming species.
- Epiphytes and understory algae are grazed by a variety of amphipods, isopods and gastropods (Birkett *et al.*, 1998b).
- Fauna include the sand tolerant anemone, *Urticina felina*, the detritivorous hermit crab, *Pagurus bernhardus* and the opportunistic tube forming annelid, *Spirobranchus triqueter*.

Seasonal and longer term change

The dominant algal species in the biotope are perennial and therefore present throughout the year. However, they do exhibit seasonality in terms of growth and reproduction. For example, maximum growth of *Furcellaria lumbricalis* occurs in March/April (Austin, 1960b) and release of carpospores and tetraspores occurs in December/January (Bird *et al.*, 1991). Reproductive bodies are present on the gametophytes of *Ahnfeltia plicata* between July and January and mature carposporophytes occur between October and July (Maggs & Poeschel, 1989). The annual algal species, for example the filamentous greens, are likely to proliferate in spring and summer in conjunction with increased irradiance and temperatures, and then die back in autumn and winter. Recruitment processes and recolonization by macroalgae are very dependent on time of year as spores are only available for limited periods. The advantage of being fertile through the winter, as in the case of *Ahnfeltia plicata*, *Furcellaria lumbricalis* and *Chondrus crispus*, is the availability of substrata for colonization as other annual species die back (Kain, 1975). Dickinson (1963) reported that *Chondrus crispus* was fertile in the UK from autumn to spring, but that the exact timing varied according to local environmental conditions. Similarly, Pybus (1977) reported that although carposporic plants were present throughout the year in Galway Bay, Ireland, maximum reproduction occurred in the winter and estimated that settling of spores occurred between January and May.

Storms and increased wave action are more likely to occur in the winter months and may cause physical damage to the community. Austin (1960b) reported damage to *Furcellaria lumbricalis* plants during storms and Sharp *et al.* (1993) reported that plants may be cast ashore by increased wave action. Dudgeon & Johnson (1992) noted wave induced disturbance of intertidal *Chondrus crispus* on shores of the Gulf of Maine, USA, during winter. 25-30% of cover of large *Chondrus*

crispus thalli was lost in one winter. Physical disruption of the algal turf is likely to promote diversity as spaces become available for colonization.

Habitat structure and complexity

Habitat complexity is provided by the mixed substratum of bedrock, cobbles, pebbles and mobile sand. It is this complexity which determines the species of algae which characterize the biotope. Only species tolerant of sand cover and sand scour, e.g. *Ahnfeltia plicata*, *Polyides rotunda* and *Furcellaria lumbricalis*, are able to persist in the community.

The dense algal turf provides shelter for a variety of fauna and sites for attachment of both epifauna (e.g. ascidians, bryozoans and hydroids) and epiphytes (Lewis, 1964).

Productivity

Primary production by the slow growing, perennial red algae which dominate the biotope is probably low. Wallentinus (1978) measured *in situ* primary production by macroalgae in the northern Baltic Sea. Productivity of *Furcellaria lumbricalis* was 0.36-0.54 mg C/g dry wt/hour. The comparative figure for *Cladophora glomerata*, a filamentous green alga was 1.47-11.38 mg C/g dry wt/hour. These figures suggest that the contribution made by the perennial algal turf to macroalgal production in the biotope is likely to be very small. Fast growing, ephemeral, annual species with rapid turnover probably account for the majority of macroalgal primary production. However, the contribution to primary production of all macroalgae in the biotope is likely to be small in comparison with the phytoplankton. Jansson & Kautsky (1976), for example, recorded annual macroscopic plant production of hard bottoms in the Baltic shallow subtidal to be approximately 4% of the total primary production, suggesting that phytoplankton are by far the most important carbon fixers. Additionally, they noted that fast growing species with rapid turnover, for example the filamentous brown algae, contributed approximately one third of macroalgal production and that there was a relatively small contribution made by the slow growing perennials.

Recruitment processes

Vadas *et al.* (1992) reviewed recruitment and mortality of early post settlement stages of benthic algae. They identified 6 intrinsic and 17 extrinsic factors affecting recruitment and mortality. They concluded that grazing, canopy and turf effects were the most important but that desiccation and water movement may be as important for the early stages. The review indicated that recruitment is highly variable and episodic and that mortality of algae at this period is high. Chance events during the early post settlement stages are therefore likely to play a large part in survival. As with all red algae, the spores of *Ahnfeltia plicata*, *Chondrus crispus*, *Furcellaria lumbricalis* and *Polyides rotunda* are non-flagellate and therefore dispersal is a wholly passive process (Fletcher & Callow, 1992). In general, due to the difficulties of re-entering the benthic boundary layer, it is likely that successful colonization is achieved under conditions of limited dispersal and/or minimum water current activity. Norton (1992) reported that although spores may travel long distances (e.g. *Ulva* sp. 35 km, *Phycodrys rubens* 5 km), the reach of the furthest propagule does not equal useful dispersal range, and most successful recruitment occurs within 10 m of the parent plants. It is expected, therefore, that recruitment of *Ahnfeltia plicata*, *Chondrus crispus*, *Furcellaria lumbricalis*, *Polyides rotunda* and the majority of other macroalgae in the biotope would occur from local populations and that establishment and recovery of isolated populations would be patchy and sporadic. Scrosati *et al.* (1994) commented that viability of spores of *Chondrus crispus* was low (<30%) and suggested that reproduction by spores probably does not contribute much to maintenance of the intertidal population in Nova Scotia, compared to vegetative growth of

gametophytes.

As and when bare substratum becomes available for colonization, for instance following storm events, it is expected that algal recruitment and succession would follow a predictable sequence (Hawkins & Harkin, 1985). Initial colonizers on bare rock are often epiphytic species, suggesting that it is competition from canopy forming algae that usually restricts them to their epiphytic habit (Hawkins & Harkin, 1985). Gradually, the original canopy or turf forming species, in this case *Ahnfeltia plicata*, *Furcellaria lumbricalis*, *Polyides rotunda* and *Chondrus crispus*, then become established. These findings suggest that interactions between macrophytes are often more important than grazing in structuring algal communities (Hawkins & Harkin, 1985).

The anemone, *Urticina felina*, disperses via a large pelagic larvae (Chia & Spaulding, 1972) or may be able to brood its offspring until they are well developed (Spaulding, 1974). Either way the species has poor dispersive powers (Sole-Cava *et al.*, 1994) and therefore is most likely to recruit from local populations.

Time for community to reach maturity

Maturity of the community is likely to be limited by the time it takes the climax, perennial algae to settle, grow and reach reproductive viability. Minchinton *et al.* (1997) documented the recovery of *Chondrus crispus* after a rocky shore in Nova Scotia, Canada, was totally denuded by an ice scouring event. Initial recolonization was dominated by diatoms and ephemeral macroalgae, followed by fucoids and then perennial red seaweeds. After 2 years, *Chondrus crispus* had re-established approximately 50% cover on the lower shore and after 5 years it was the dominant macroalga at this height, with approximately 100% cover. The authors pointed out that although *Chondrus crispus* was a poor colonizer, it was the best competitor. *Furcellaria lumbricalis* grows even more slowly than *Chondrus crispus* (Bird *et al.*, 1979) and may take 5 years to reach fertility (Austin, 1960b).

It is expected that, although the species which characterize the biotope would probably establish themselves after 2-3 years, a climax reproductive community may not be achieved until 5 years or more.

Additional information

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Preferences & Distribution

Habitat preferences

Depth Range	5-10 m
Water clarity preferences	
Limiting Nutrients	Nitrogen (nitrates), Phosphorus (phosphates)
Salinity preferences	Full (30-40 psu)
Physiographic preferences	Open coast
Biological zone preferences	Infralittoral
Substratum/habitat preferences	Bedrock, Cobbles, Pebbles, Sand
Tidal strength preferences	Moderately Strong 1 to 3 knots (0.5-1.5 m/sec.), Weak < 1 knot (<0.5 m/sec.)
Wave exposure preferences	Exposed, Moderately exposed

Other preferences

Additional Information

Species composition

Species found especially in this biotope

- [Ahnfeltia plicata](#)

Rare or scarce species associated with this biotope

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Additional information

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The biotope description and characterizing species is taken from Connor *et al.* (2004). This biotope occurs on low-lying rock surrounded by mobile sand and often subject to burying by the sand, with a turf of resilient red seaweeds *Chondrus crispus*, *Polyides rotunda* and *Ahnfeltia plicata* typically protruding through the sand on the upper surfaces of the rock. The sensitivity assessments are based on these named characterizing species. Other scour-tolerant seaweeds that may be present include *Rhodomela confervoides*, *Phyllophora pseudoceranoides*, *Phyllophora crispa*, *Furcellaria lumbricalis*, *Gracilaria gracilis*, *Ceramium rubrum*, *Plocamium cartilagineum*, *Heterosiphonia plumosa*, *Cryptopleura ramosa* and *Dilsea carnosa*. The sensitivity of these is considered generally. Coralline crusts typically cover the rock, while scattered individuals of the brown seaweeds *Halidrys siliquosa*, *Cladostephus spongiosus*, *Dictyota dichotoma* and *Laminaria saccharina* can be present. Evidence is presented for the sensitivity of these species and the large anthozoan *Urticina felina* where available.

Resilience and recovery rates of habitat

This biotope occurs in areas subject to chronic disturbance from scour and sediment mobility, these factors maintain the biotope by preventing the growth of larger and more-long lived species that are typical of more stable biotopes occurring in the infralittoral. As an early successional biotope subject to frequent perturbation, species present will either be adapted to resist the stressors acting on the biotope or to recover rapidly. As the substratum is relatively mobile, it is likely that the scattered kelps and other larger brown algae, such as *Halidrys siliquosa* that occur in this biotope are usually present as smaller, seasonal recruits that are removed during periods of disturbance and regrow annually. These larger species do not define the biotope and recovery of this element is assessed as 'High' at all levels of impact (resistance is High, Medium, Low or None).

The turf forming red algae is the key group characterizing this biotope. Depending on the level of impact, recovery of the turf may occur through repair and regrowth of damaged fronds, regrowth from crustose bases or via recolonization of rock surfaces where all the plant material is removed. Although there are few case studies following recovery some general trends are apparent. All the red algae (Rhodophyta) exhibit distinct morphological stages over the reproductive life history. This phenomenon is known as heterotrichy or heteromorphy and describes cases where the algal thallus consists of two parts; a prostrate creeping system exhibiting apical growth and functioning as a holdfast. The thalli can regrow from these crusts where they remain supporting recovery of the biotope (Mathieson & Burns, 1975; Dudgeon & Johnson, 1992). The basal crusts are perennial, tough, resistant stages that prevent other species from occupying the rock surface and allow rapid regeneration and where these remain they provide a significant recovery mechanism. The bases can spread laterally across rock and for species such the characterizing *Chondrus crispus* they coalesce over time and can form an extensive crust on rock (Taylor *et al.*, 1981). Some species exhibit annual growth and die back patterns. In *Phyllophora pseudoceranoides* for example the plant is perennial but blades are lost and regrown each year (Molenaar & Breeman, 1994). Similarly *Plocamium cartilagineum*, loses blades in winter in wave exposed conditions while the crustose bases survive and spread laterally (Kain, 1987). Some temporal variation in abundance and biomass is therefore normal within this biotope. Resistant crustose bases enable the turf of red algae and the crustose corallines to withstand and recover from physical disturbance and scour while preventing the establishment of other species.

Of the characterizing species *Chondrus crispus* is the most studied red algae within this biotope due to its commercial value. Growth patterns vary seasonally with the highest biomass usually in late Spring or Summer and lowest in Winter (Fernández & Menéndez, 1991). Pybus (1977) estimated that *Chondrus crispus* from Galway Bay, Ireland, reached maturity approximately 2 years after the initiation of the basal disc, at which stage, the fronds were approximately 12 cm in length. The fronds of *Chondrus crispus* typically have a life of 2-3 years (Taylor, cited in Pringle & Mathieson, 1986) but may live up to 6 years in sheltered waters (Harvey & McLachlan, 1973). Dickinson (1963) reported that *Chondrus crispus* was fertile in the UK from autumn to spring, but that the exact timings varied according to local environment. Similarly, Pybus (1977) reported that in Galway Bay, Ireland, maximum reproduction occurred in the winter and estimated that settling of spores occurred between January and May. In Nova Scotia, and most likely other areas where conditions are not optimal for reproduction and settlement, reproduction by spores probably does not contribute much to maintenance of population of *Chondrus crispus* compared to vegetative growth of gametophytes (Scrosati *et al.*, 1994). Most of the evidence for recovery of *Chondrus crispus* is based on intertidal experiments that simulate the effects of different harvesting mechanisms and intensities (Macfarlane, 1952; Mathieson & Burns, 1975). Macfarlane (1952) in a series of experiments identified that where *Chondrus crispus* was removed by cutting of fronds or thorough raking (leaving the crusts undamaged) the turf had recovered and there were no notable differences between the experimental areas and control sites. However, where the crusts were removed by scraping or damaged the experimental plots were still recovering nearly two years after the treatment. Following experimental harvesting by drag raking (hodfasts and small blades undamaged) in New Hampshire, USA, populations recovered to 1/3 of their original biomass after 6 months and totally recovered after 12 months (Mathieson & Burns, 1975). The authors suggested that control levels of biomass and reproductive capacity are probably reestablished after 18 months of regrowth (where crusts are not removed). It was noted however, that time to recovery was much extended if harvesting occurred in the winter, rather than the spring or summer (Mathieson & Burns, 1975).

Minchinton *et al.* (1997) documented the recovery of *Chondrus crispus* after a rocky shore in Nova Scotia, Canada, was totally denuded by an ice scouring event. Initial recolonization was dominated by diatoms and ephemeral macroalgae, followed by furoids and then perennial red seaweeds. After 2 years, *Chondrus crispus* had re-established approximately 50% cover on the lower shore and after 5 years it was the dominant macroalga at this height, with approximately 100% cover. The authors pointed out that although *Chondrus crispus* was a poor colonizer, it was the best competitor. Similarly MacFarlane (1952) reports that the particularly harsh winter of 1947/48 destroyed *Chondrus* beds near Pubnico. By the next summer, the annual brown alga *Chordaria* had colonized the area, and by the summer of 1950, *Fucus* had taken over as the dominant successional stage. *Chondrus* did not noticeably start to grow back in the area until summer 1951, four years later. Pringle and Semple (1980) estimated it would take about four years for a bare patch in a *Chondrus* bed to fill in with harvestable plants and five to ten years for *Chondrus* to re-establish in barren areas. The applicability of recovery patterns and rates from intertidal biotopes to this scoured, subtidal biotope is not clear

No information was found concerning the longevity of *Ahnfeltia plicata*. However, it is a slow maturing perennial (Dickinson, 1963) and the thallus survives several years without considerable losses (Lüning, 1990). Maggs & Pueschel (1989) reported that mature gametophytes in Nova Scotia varied in size from 3-21 cm, and that 14 months after germination, gametophyte fronds had reached up to 5 cm in length. No definitive information was found concerning age at maturity. However, Maggs & Pueschel (1989) made observations of *Ahnfeltia plicata* from Nova Scotia. Tetrasporophyte crusts matured and released tetraspores after 15 months. The associated red

algae *Furcellaria lumbricalis* also grows very slowly compared to some other red algae (Bird et al., 1979) and takes a long time to reach maturity. For example, Austin (1960b) reported that in Wales, *Furcellaria lumbricalis* typically takes 5 years to attain fertility.

The spores of red algae are non-motile (Norton, 1992) and therefore entirely reliant on the hydrographic regime for dispersal. Norton (1992) reviewed dispersal by macroalgae and concluded that dispersal potential is highly variable, recruitment usually occurs on a much more local scale, typically within 10 m of the parent plant. Hence, it is expected that the red algal turf would normally rely on recruit from local individuals and that recovery of populations via spore settlement, where adults are removed, would be protracted.

Coralline crust is a generic term that in UK biotopes refers to nongeniculate (crustose) species from the family Corallinacea that could include *Lithophyllum incrustans*, *Lithothamnion* spp. and *Phymatolithon* spp. Due to the lack of evidence the assessments are generic, although species specific information is presented where available. A number of papers by Edyvean & Ford (1984a & b; 1986; 1987) describe aspects of reproduction and growth of encrusting coralline, *Lithophyllum incrustans*. Studies by Edyvean & Forde (1987) in populations of *Lithophyllum incrustans* in Pembroke south-west Wales suggest that reproduction occurs on average early in the third year. Reproduction may be sexual or asexual. Populations release spores throughout the year but abundance varies seasonally, with the populations studied in Cullercoats Bay, and Lannacombe Bay (North East and South West England, respectively) producing less spores in the summer. Spore release is initiated by changes in temperature or salinity (see relevant pressure information) at low tide so that spore dispersal is restricted to within the tide pool enhancing local recruitment. Within subtidal biotopes this is not possible and recruitment success may be altered (although this may be compensated by avoidance of desiccation). Spore survival is extremely low with only a tiny proportion of spores eventually recruiting to the adult population (Edyvean & Ford, 1986). The spores are released from structures on the surface called conceptacles, these are formed annually and subsequently buried by the new layer of growth. Plants can be aged by counting the number of layers of conceptacles. Edyvean & Ford (1984a) found that the age structure of populations sampled from Orkney (Scotland) Berwick (northern England) and Devon (England) were similar, mortality seemed highest in younger year classes with surviving individuals after the age of 10 years appear relatively long-lived (up to 30 years). In St Mary's Northumberland, the population was dominated by the age 6-7 year classes (Edyvean & Ford, 1984a). Growth rates were highest in young plants measured at Pembroke (south-west Wales) with an approximate increase in diameter of plants of 24 mm in year class 0 and 155 mm in year 1 and slowing towards an annual average horizontal growth rate of 3mm/year (Edyvean & Ford, 1987).

Some repair of damaged encrusting coralline occurs through vegetative growth. Chamberlain (1996) observed that although *Lithophyllum incrustans* was quickly affected by oil during the Sea Empress spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area. Recolonization by propagules is also an important recovery mechanism, Airoidi (2000) observed that encrusting coralline algae recruited rapidly on to experimentally cleared subtidal rock surfaces in the Mediterranean Sea, reaching up to 68% cover in 2 months.

Little information is available for life-history and reproductive strategies to inform a recovery assessment for the large anemone *Urticina felina*. Some damage to individuals can be repaired, for example removal of tentacles by clipping does not alter behaviour and the tentacle regenerates within a few days (Mercier et al., 2011). Recovery is likely to be slow in populations where nearby individuals do not exist as the species broods juvenile stages and does not have a pelagic dispersal

phase. Dispersal ability was considered to be poor in the similar species *Urticina eques* (Solé-Cava *et al.* 1994). The large size, slow growth rate and evidence from aquarium populations suggest that *Urticina felina* is long lived (Hiscock, pers comm.). Adults can detach from the substratum and relocate but locomotive ability is very limited. Impacts that remove large proportions of the population over a wide area will effectively reduce the availability of colonists. However, the species colonized ex-HMS *Scylla* in the fourth year of the vessel being on the seabed (Sköld *et al.*, 2001).

Resilience assessment. Growth, maturity and longevity vary between the turf forming red algae species. Although some general trends are apparent. Recovery rates, for example, will be greatly influenced by whether the crust stages remain from which the thalli can regrow of the characterizing red algae. Biotope resilience is assessed as 'High' where resistance is 'High'. Where resistance is assessed as 'Medium' (loss of <25% of individuals or cover) and the bases remain then recovery is assessed as 'High' based on regrowth from crusts and remaining plants. Where resistance is assessed as 'Medium', 'Low' or 'None', and a high proportion of bases are lost, then recovery will depend on either vegetative regrowth from remaining bases or the supply of propagules from neighbouring populations. Dispersal is limited and propagule supply will be influenced site-specific factors, particularly local water transport. Where resistance is assessed as 'Low' or 'None' then resilience is assessed as 'Medium' (2-10 years) for the red algal turf, encrusting corallines and *Urticina felina*. Biotope composition may be altered in favour of species with better dispersal ability and higher growth rates but some variation is natural.

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 recognizable 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 Q: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High

The key characterizing red algal species found in this biotope have broad geographic distributions and are found in warmer waters than those around the UK. As this biotope is subtidal it is protected from exposure to air so that the thermal regime is more stable and desiccation is not a factor. Examples of distribution and thermal tolerances tested in laboratory experiments are provided as evidence to support assessments. Populations can acclimate to prevailing conditions which can alter tolerance thresholds and care should therefore be used when interpreting reported tolerances.

The key characterizing species *Chondrus crispus* has a wide distribution, it is found extensively throughout Europe and North America records also recorded under a number of synonyms from

Africa and Asia (Guiry & Guiry, 2015). Spore germination in *Chondrus crispus* appears to be temperature dependent with spores discharged at temperatures of 5°C failing to germinate although in laboratory culture at 10°C spores were viable all year round (Bhattacharya, 1985). In New Hampshire, USA, *Chondrus crispus* grows abundantly in waters with an annual variation in surface temperature from -1 to +19°C (Mathieson & Burns, 1975). The optimum temperature for growth has been reported as 10-15°C (Fortes & Lüning, 1980), 15°C (Bird *et al.*, 1979), 15-17°C (Tasende & Fraga, 1999) and 20°C (Simpson & Shacklock, 1979). Above the optimum temperature, growth rate is reported to decline (Bird *et al.*, 1979; Simpson & Shacklock, 1979). Compared to *Chondrus crispus* plants grown at 5°C, plants grown at 20°C had higher growth rates in terms of length, biomass, surface area, dichotomy and branch production. The differences resulted in growth of morphologically more complex thalli at higher temperatures with more efficient nutrient exchange and light harvesting (Kuebler & Dudgeon, 1996). *Chondrus crispus* plants acclimated to growth at 20°C (vs. 5°C) had higher levels of chlorophyll a and phycobilins, resulting in higher rates of light limited photosynthesis for a given photon flux density (Kuebler & Davison, 1995). Plants grown at 20°C were able to maintain constant rates of light saturated photosynthesis at 30°C for 9 hours. In contrast, in plants acclimated to 5°C, light saturated photosynthetic rates declined rapidly following exposure to 30°C (Kuebler & Davison, 1993). Prince & Kingsbury (1973) reported cessation of growth in *Chondrus crispus* cultures at 26°C, first mortality of spores at 21.1°C and total mortality of spores at 35-40°C, even if exposed for just 1 minute.

The key characterizing species *Ahnfeltia plicata*, has a very wide geographic range, occurring from northern Russia to Portugal. The species is therefore likely to be tolerant of higher temperatures than it experiences in Britain and Ireland. Lüning & Freshwater (1988) incubated *Ahnfeltia plicata* from British Columbia at a range of temperatures for 1 week and tested their survivability by ability to photosynthesize at the end of the incubation period. The species survived from the coldest temperature tested (-1.5°C) to 28 °C. Total mortality occurred at 30 °C. Lüning & Freshwater (1988) suggested that *Ahnfeltia plicata* was therefore amongst the group of most eurythermal heat tolerant algae. Haglund *et al.* (1987) incubated *Ahnfeltia plicata* from the subtidal in Sweden at a range of temperatures and measured photosynthetic rate. There were no significant results, but photosynthetic rate appeared to be optimal at 15°C and decreased either side of this temperature. The key characterizing species *Polyides rotunda*, is found throughout the North Atlantic Ocean and related populations occur in the North Pacific. Growth and survival was tested over a temperature range of -5 to 30 °C. *Polyides rotunda* tolerated temperatures from -5 to 27 °C, grew well from 5 to 25 °C, and had a broad optimal range of 10-25 °C. This species tolerated 3 months in darkness at 0 °C (Novaczek & Breeman, 1990).

The associated species *Furcellaria lumbricalis* has a wide geographic range, occurring in Europe from northern Norway to the Bay of Biscay. Novaczek & Breeman (1990) recorded that specimens of *Furcellaria lumbricalis* grew well in the laboratory from 0-25°C with optimal growth between 10 and 15°C. Growth ceased at 25°C and 100% mortality resulted after 3 months exposure to 27°C. Similarly, Bird *et al.* (1979) recorded optimum growth at 15°C and cessation of growth at 25°C with associated necrosis of apical segments. Samples of *Phyllophora pseudoceranoides* from Nova Scotia, Iceland, Roscoff and Helgoland grew from 3 °C to 25 °C and survived from -2 °C to 27 °C but not 30 °C. Lüning (1984) found that *Phyllophora pseudoceranoides* collected from Helgoland died after 1 week exposure to 33 °C (Molenaar & Breeman, 1994). Edyvean & Ford (1984b) suggest that populations of *Lithophyllum incrustans* are affected by temperature changes and salinity and that temperature and salinity 'shocks' induce spawning but no information on thresholds was provided (Edyvean & Ford, 1984b). Populations of *Lithophyllum incrustans* were less stable in tide pools with a smaller volume of water that were more exposed to temperature and salinity changes due to

lower buffering capacity. Sexual plants (or the spores that give rise to them) were suggested to be more susceptible than asexual plants to extremes of local environmental variables (temperature, salinity etc.) as they occur with greater frequency at sites where temperature and salinity were more stable (Edyvean & Forde, 1984b). *Lithophyllum incrustans* in the UK is close to the northern edge of its range and is likely to tolerate increased temperatures.

Sensitivity assessment. The geographic distribution and laboratory experiments indicate that the key characterizing species and many of the associated red algal turf species would tolerate either an acute or chronic increase in temperature at the pressure benchmark, although some sub-lethal decreases in photosynthesis may occur where temperatures exceed the optimal. Gamete release may also depend on lower winter temperatures and therefore non-lethal effects on reproduction may occur where optimal temperatures are exceeded. As these effects do not result in mortality, resistance is assessed as 'High' and recovery as 'High' (by default) so that the biotope is considered to be 'Not sensitive' to short-term (not greater than a year) changes at the pressure benchmark..

Temperature decrease (local)

High

Q: High A: Medium C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: Medium C: High

The key characterizing red algal species found in this biotope have broad geographic distributions and are found in colder waters than those around the UK. As this biotope is subtidal it is protected from exposure to air so that the thermal regime is more stable. Examples of distribution and thermal tolerances tested in laboratory experiments are provided as evidence to support assessments. Populations can acclimate to prevailing conditions which can alter tolerance thresholds and care should therefore be used when interpreting reported tolerances.

The key characterizing species, *Chondrus crispus* has a broad geographical distribution (Guiry & Guiry, 2015) and throughout the range experience wide variation in temperatures (although local populations may be acclimated to the prevailing thermal regime). In New Hampshire, USA, *Chondrus crispus* grows abundantly in waters with an annual variation in surface temperature from -1 to +19 °C (Mathieson & Burns, 1975). The photosynthetic rate of *Chondrus crispus* recovered after 3hrs at -20 °C but not after 6 hrs (Dudgeon *et al.* (1989). Frond bleaching and declines in photosynthesis and growth also occur in long-term experimental exposure to periodic freezing in *Chondrus crispus* (Dudgeon *et al.*, 1990). Plants from Maine, USA, were frozen at -5 °C for 3 hours a day for 30 days. Photosynthesis was reduced to 55 % of control values, growth rates were reduced and fronds were eventually bleached and fragmented resulting in biomass losses. Additionally, fronds of *Chondrus crispus* which were frozen daily had higher photosynthetic rates following subsequent freezing events than unfrozen controls, indicating that the species is able to acclimate to freezing conditions (Dudgeon *et al.*, 1990). Spore germination in *Chondrus crispus* appears to be temperature dependent with spores discharged at temperatures of 5 °C failing to germinate although in laboratory culture at 10 °C spores were viable all year round (Bhattacharya, 1985). Acute or chronic changes in temperature below 5 °C may therefore reduce reproductive success although reproduction and vegetative growth in warmer months should compensate for any reduction in output.

Ahnfeltia plicata has a very wide geographic range, occurring from northern Russia to Portugal. The species is therefore likely to be tolerant of lower temperatures than it experiences in Britain and Ireland. Lüning & Freshwater (1988) incubated *Ahnfeltia plicata* from British Columbia at a range of temperatures for 1 week and tested their survivability by ability to photosynthesize at the end of the incubation period. The species survived from the coldest temperature tested (-1.5 °C) to 28 °C.

Haglund *et al.* (1987) incubated *Ahnfeltia plicata* from the subtidal in Sweden at a range of temperatures and measured photosynthetic rate. There were no significant results, but photosynthetic rate appeared to be optimal at 15 °C and decreased either side of this temperature.

Growth and survival of the key characterizing species, *Polyides rotunda* was tested over a temperature range of -5 to 30 °C. *Polyides rotunda* tolerated temperatures from -5 to 27 °C, grew well from 5 to 25 °C, and had a broad optimal range of 10-25 °C (Novaczek & Breeman, 1990). This species tolerated 3 months in darkness at 0 °C (Novaczek & Breeman, 1990).

Edyvean & Forde (1984b) suggest that populations of *Lithophyllum incrustans* are affected by temperature changes and salinity and that temperature and salinity 'shocks' induce spawning but no information on thresholds was provided (Edyvean & Ford, 1984b).

Furcellaria lumbricalis has a wide geographic range, occurring in Europe from northern Norway to the Bay of Biscay. Novaczek & Breeman (1990) recorded that specimens of *Furcellaria lumbricalis* grew well in the laboratory from 0-25 °C with optimal growth between 10 and 15 °C. Growth ceased at 25 °C and 100 % mortality resulted after 3 months exposure to 27 °C. Similarly, Bird (1979) recorded optimum growth at 15 °C.

Sensitivity assessment. The key characterizing species occur over a wide geographical range and can tolerate temperatures below 0 °C. Reduced temperatures may result in suboptimal growth and may affect reproduction. Biotope resistance is assessed as 'High' as these effects do not result in mortality and resilience is assessed as 'High', so that the biotope is not considered to be sensitive to this pressure.

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

This biotope occurs in full salinity (Connor *et al.*, 2004) a change above the pressure benchmark is assessed as a change to above 40 ppt. Species within this biotope such as *Chondrus crispus* that are also found in intertidal biotopes including rock pools are likely to have some form of physiological adaptations to increases in salinity as these habitats encounter more variation in salinity. However, local populations are likely to be acclimated to the prevailing conditions even over small spatial distances and gradients and caution should be used in extrapolating sensitivities.

More evidence was found to assess *Chondrus crispus* than the other turf forming red algae. *Chondrus crispus* is found in a range of salinities across its range and has been reported from sites with yearly salinity range 0-10 psu and 10-35 psu (Lindgren & Åberg 1996) and sites from an average of 26-32 psu. However, at different salinities the ratio between the abundance of the tetrasporophyte phase and the gametophyte alters (Guidone & Grace, 2010). Mathieson & Burns (1971) recorded maximum photosynthesis of *Chondrus crispus* in culture at 24 psu, but rates were comparable at 8, 16 and 32 psu. Photosynthesis continued up to 60 psu. Bird *et al.* (1979) recorded growth of Canadian *Chondrus crispus* in culture between 10 and 50 psu, with a maximum at 30 psu. *Chondrus crispus* would therefore appear to be euryhaline and tolerant of a range of salinities.

Haglund *et al.* (1987) studied photosynthetic rate of *Ahnfeltia plicata* from the subtidal in Sweden and found that, at constant temperature, rate increased up to the maximum salinity tested (33 psu).

Furcellaria lumbricalis is a euryhaline species which occurs in a wide range of salinity conditions down to 6-8 psu (Bird et al., 1991). In the Kattegat and the Gulf of St Lawrence, it is reported to compete well with other species at salinities ranging from 25-32 psu (see review by Bird et al., 1991). Growth experiments in the laboratory revealed that optimum growth occurred at 20 psu, the species grew well at 10 psu and 30 psu, but that growth declined above 30 psu to negligible levels at 50 psu (Bird et al., 1979). It is expected that an increase in salinity may cause reduced growth and fecundity, but that mortality is unlikely.

Edyvean & Ford (1984b) suggest that populations of the crustose coralline *Lithophyllum incrustans* are affected by temperature changes and salinity and that temperature and salinity 'shocks' induce spawning but no information on thresholds was provided (Edyvean & Ford, 1984b). Populations of *Lithophyllum incrustans* were less stable in rockpools with a smaller volume of water that were more exposed to temperature and salinity changes due to lower buffering capacity. Sexual plants (or the spores that give rise to them) were suggested to be more susceptible than asexual plants to extremes of local environmental variables (temperature, salinity etc.) as they occur with greater frequency at sites where temperature and salinity were more stable (Edyvean & Ford, 1984b).

Sensitivity assessment. No specific evidence was found for the salinity tolerance of the key characterizing species *Polyides rotunda*. Based on the reported salinity tolerances of *Chondrus crispus* and other red algae species, it is considered that an increase at the pressure benchmark may lead to some changes in the composition of the red algal turf that characterizes this biotope and reduce species richness and abundance, although some more tolerant species may persist. Resistance (of the biotope) is therefore assessed as 'Low' and resilience as 'Medium' and biotope sensitivity is assessed as 'Medium'.

Salinity decrease (local)

Low

Q: High A: High C: Medium

Medium

Q: High A: Low C: Medium

Medium

Q: High A: Low C: Medium

As this biotope is present in full salinity (30-35 ppt, Connor *et al.*, 2004), the assessed change at the pressure benchmark is a reduction in salinity to a variable regime (18-35 ppt) or reduced regime (18-30 ppt). Populations can acclimate to local conditions and caution should be used in extrapolating observations from areas where populations are likely to be adapted to the prevailing conditions. A comparative study of salinity tolerances of macroalgae collected from North Zealand in the South Kattegat (Denmark) where salinity is 16 psu. Showed that species generally had a high tolerance (maintained more than half of photosynthetic capacity) to short-term exposure (4 days) to salinities lower than 3.7. However, tolerances varied between species with *Ahnfeltia plicata*, *Phyllophora pseudoceranoides* and *Chondrus crispus* exhibiting greater tolerance than *Rhodomela confervoides* (Larsen & Sand-Jensen, 2006). The result illustrates that responses to this pressure will vary between species and that a change at the pressure benchmark is likely to alter the composition of the red algal turf that characterizes the biotope and may alter the biomass and density of more tolerant species.

Chondrus crispus is found in a range of salinities across its range and has been reported from sites with yearly salinity range 0-10 psu and 10-35 psu (Lindgren & Åberg 1996) and sites from an average of 26-32 psu. However, at different salinities the ratio between the abundance of the tetrasporophyte phase and the gametophyte alters (Guidone & Grace, 2010). Mathieson & Burns (1971) recorded maximum photosynthesis of *Chondrus crispus* in culture at 24 psu, but rates were comparable at 8, 16 and 32 psu. Photosynthesis continued up to 60 psu. Bird *et al.* (1979) recorded growth of Canadian *Chondrus crispus* in culture between 10 and 50 psu, with a maximum at 30

psu. *Chondrus crispus* would therefore appear to be euryhaline and tolerant of a range of salinities.

Ahnfeltia plicata occurs over a very wide range of salinities. The species penetrates almost to the innermost part of Hardanger Fjord in Norway where it experiences very low salinity values and large salinity fluctuations due to the influence of snowmelt in spring (Jorde & Klavestad, 1963). *Ahnfeltia plicata* penetrates further than the euryhaline species, *Polyides rotunda*, and probably has a similar salinity tolerance to *Furcellaria lumbricalis*, which is limited only by the 4 psu isohaline (see review by Bird *et al.*, 1991). Haglund *et al.* (1987) studied photosynthetic rate of *Ahnfeltia plicata* from the subtidal in Sweden and found that, at constant temperature, photosynthesis was positively correlated with salinity between 15 and 33 psu. It is likely therefore that the benchmark decrease in salinity would not result in mortality, but photosynthesis would not be optimal and so growth and reproduction may be compromised.

Furcellaria lumbricalis occurs in the lowest category on the salinity scale (Connor *et al.*, 1997a) and therefore probably relatively tolerant of decreases in salinity. The species forms extensive populations in the main basin of the Baltic Sea where salinity is 6-8 psu in the upper 60-70 m and its extension into the Gulfs of Bothnia and Finland is limited by the 4 psu isohaline (see review by Bird *et al.*, 1991).

Rhodomela confervoides shows local acclimation to prevailing salinity regimes in the brackish Baltic Sea, with populations surviving at 11 ppt or 2.5 ppt depending on the local salinity where collected (Rietema, 1995).

Edyvean & Ford (1984b) suggest that populations of the crustose coralline *Lithophyllum incrustans* are affected by temperature changes and salinity and that temperature and salinity 'shocks' induce spawning but no information on thresholds was provided (Edyvean & Ford, 1984b). Populations of *Lithophyllum incrustans* were less stable in tide pools with a smaller volume of water that were more exposed to temperature and salinity changes due to lower buffering capacity. Sexual plants (or the spores that give rise to them) were suggested to be more susceptible than asexual plants to extremes of local environmental variables (temperature, salinity etc.) as they occur with greater frequency at sites where temperature and salinity were more stable (Edyvean & Ford, 1984b).

The anemone *Urticina felina* occurs in estuaries e.g. the Thames estuary at Mucking and the River Blackwater estuary (Davis, 1967). Braber and Borghouts (1977) found that *Urticina* (as *Tealia*) *felina* penetrated to about the 11ppt Chlorinity isohaline (corresponding to about 20psu based on conversion rates) at mid tide during average water discharge in the Westerschelde estuary suggesting that it would be tolerant of reduced salinity conditions. Intertidal and rock pool individuals will also be subject to variations in salinity because of precipitation on the shore; albeit for short periods on the lower shore. Therefore, the species seems to have a high tolerance to reduction in salinity but may have to retract tentacles and suffer reduced opportunity to feed.

Sensitivity assessment. Two of the key defining species, *Chondrus crispus* and *Ahnfeltia plicata* are euryhaline and occur over a range of salinities. Other species associated with the biotope such as the red algae *Furcellaria lumbricalis* and *Urticina felina* are likely to tolerate a reduction in salinity at the pressure benchmark. Some changes in local composition may occur as a response to a decrease in salinity but may not significantly alter it from the biotope description. Resistance (of the biotope) is therefore assessed as 'Medium' and resilience as 'Medium' (as bases may not remain to enhance recovery), and biotope sensitivity is judged to be 'Medium'.

Water flow (tidal current) changes (local)**High**

Q: High A: Medium C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: Medium C: High

This biotope occurs across a range of flow speeds, from moderately strong (0.5-1.5 m/s) to areas where water flow is negligible (Connor *et al.*, 2004). As water velocity increases foliose macroalgae can flex and reconfigure to reduce the size of the alga when aligned with the direction of flow, this minimises drag and hence the risk of dislodgement (Boller & Carrington, 2007). These characteristics allow these species to persist in areas that experience a range of flow speeds. Biogenic habitat structures, including the fronds of algae, reduce the effects of water flows on individuals by slowing and disrupting flow. Boller and Carrington (2006) found that the canopy created by a turf of *Chondrus crispus* reduced drag forces on individual plants by 15-65%. The compact, turf forming growth of the algal species will therefore reduce water flow and the risk of displacement through turbulence and friction.

The characterizing red algal turf is unlikely to be affected by changes in water flow alone as these can endure high current speeds. For example, *Chondrus crispus* occurs at intertidal sites in Maine, USA experiencing peak Autumn flow speeds as measured by current meters of 9.2 m/s and 5.8 m/s.

The anemone *Urticina felina* favours areas with strong tidal currents (Holme & Wilson, 1985; Migné & Davout, 1997a) although it is also found in calmer and sheltered areas as well as deep water. Records from the MNCR database were used as a proxy indicator of the resistance to water flow changes by this species by Tillin & Tyler-Walters (2014). The records indicate the water flow categories for *biotopes* characterized by *Urticina felina* range from very strong to very weak (negligible) (negligible to >3m/s) suggesting that a change in the maximum water flow experienced by mid-range populations for the periods of peak spring tide flow would not have negative effects (Tillin & Tyler-Walters, 2014).

Scour is a key factor structuring this biotope, changes in the flow may increase or decrease sediment transport and associated scour. Reductions in flow may lead to increased deposition of silts and alter the sediment character. An increase in water flow at the pressure benchmark may re-suspend and remove sand particles which are less cohesive than mud particles. The level of impact will depend on site specific hydrodynamic and sediment conditions. Some periodic movement of sediments and changes in coverage is part of the natural temporal variation and periodic disturbances from storms may be more important than water flow in maintaining the character of the biotope, particularly in sheltered areas.

Sensitivity assessment. As the biotope can occur in a range of flow speeds, resistance of the biotope to changes in water flow that do not alter the substrata is assessed as 'High' and resilience as 'High' (by default) so that the biotope is assessed as 'Not sensitive'.

Emergence regime 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

Changes in emergence are not relevant to this biotope (group) which is restricted to fully subtidal habitats. Many of the species found in this biotope such as *Ahnfeltia plicata*, *Chondrus crispus*, *Rhodomela confervoides* occur intertidally but a change in emergence would alter the character of the habitat and lead to biotope reclassification.

Wave exposure changes (local)**High**

Q: High A: Medium C: Medium

High

Q: High A: High C: High

Not sensitive

Q: High A: High C: High

This biotope is recorded from locations that are judged to range from extremely exposed or exposed (Connor *et al.*, 2004). The degree of wave exposure influences wave height, as in more exposed areas with a longer fetch waves would be predicted to be higher. As this biotope occurs across a range of exposures, this was therefore considered to indicate, by proxy, that biotopes in the middle of the wave exposure range would tolerate either an increase or decrease in significant wave height at the pressure benchmark. As water movement increases foliose macroalgae can flex and reconfigure to reduce the size of the alga when aligned with the direction of flow, this minimises drag and hence the risk of dislodgement (Boller & Carrington, 2007). These characteristics allow these species to persist in areas that experience a range of flow speeds resulting from wave action. The crustose corallines associated with this biotope have a flat growth form and are unlikely to be dislodged by increased wave action.

Records from the MNCR database were used as a proxy indicator of the resistance to wave height changes by *Urticina felina*. The latest version of the JNCC National Biodiversity Database was used as the source of the MNCR data. The records indicate the wave exposure categories for *biotopes* characterized by members of this ecological group as extremely sheltered; very sheltered; sheltered; moderately exposed; exposed; very exposed (Tillin & Tyler-Walters, 2014).

Sensitivity assessment. The biotope is found across a range of wave exposures, mid-range populations are considered to have 'High' resistance to a change in significant wave height at the pressure benchmark. 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.

Contamination at levels greater than the pressure benchmark may adversely impact the biotope. Little information was found concerning the intolerance of *Chondrus crispus* to heavy metals. Burdin & Bird (1994) reported that both gametophyte and tetrasporophyte forms accumulated Cu, Cd, Ni, Zn, Mn and Pb when immersed in 0.5 mg/l solutions for 24 hours. No effects were reported however, and no relationship was detected between hydrocolloid characteristics and heavy metal accumulation. Bryan (1984) suggested that the general order for heavy metal toxicity in seaweeds is: Organic Hg > inorganic Hg > Cu > Ag > Zn > Cd > Pb. Cole *et al.* (1999) reported that Hg was very toxic to macrophytes. The sub-lethal effects of Hg (organic and inorganic) on the sporelings of an intertidal red algae, *Plumaria elegans*, were reported by Boney (1971), 100 % growth inhibition was caused by 1 ppm Hg.

Hydrocarbon & PAH 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

Contamination at levels greater than the pressure benchmark may adversely impact the biotope. The long-term effects on *Chondrus crispus* of continuous doses of the water accommodated fraction (WAF) of diesel oil were determined in experimental mesocosms (Bokn *et al.*, 1993). Mean hydrocarbon concentrations tested were 30.1 µg/l and 129.4 µg/l. After 2 years, there were no demonstrable differences in the abundance patterns of *Chondrus crispus*. Kaas (1980) (cited in Holt *et al.*, 1995) reported that the reproduction of adult *Chondrus crispus* plants on the French coast was normal following the *Amoco Cadiz* oil spill. However, it was suggested that the development of young stages to adult plants was slow, with biomass still reduced 2 years after the event. O'Brien & Dixon (1976) and Grandy (1984) (cited in Holt *et al.*, 1995) comment on the high intolerance of red algae to oil/dispersant mixtures, but it is unclear which factor is responsible for the intolerance.

Crump *et al.* (1999) described "dramatic and extensive bleaching" of '*Lithothamnium*' following the *Sea Empress* oil spill. Observations following the *Don Marika* oil spill (K. Hiscock, pers. comm.) were of rockpools with completely bleached coralline algae. However, Chamberlain (1996) observed that although *Lithophyllum incrustans* was affected in a short period of time by oil during the *Sea Empress* spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area.

The examples stated refer to intertidal areas, where the contaminants consist of lighter fractions and float on water subtidal habitats will be less exposed.

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.

Contamination at levels greater than the pressure benchmark may adversely impact the biotope. No evidence was found specifically relating to the intolerance of *Chondrus crispus* to synthetic chemicals. However, inferences may be drawn from the sensitivities of red algal species generally. O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil or dispersant contamination, possibly due to the susceptibility of phycoerythrins to destruction. They also report that red algae are effective indicators of detergent damage since they undergo colour changes when exposed to relatively low concentration of detergent. Smith (1968) reported that 10 ppm of the detergent BP 1002 killed the majority of specimens in 24hrs in toxicity tests, although *Chondrus crispus* was amongst the algal species least affected by the detergent used to clean up the *Torrey Canyon* oil spill. Laboratory studies of the effects of oil and dispersants on several red algal species concluded that they were all sensitive to oil/dispersant mixtures, with little difference between adults, sporelings, diploid or haploid life stages (Grandy, 1984, cited in Holt *et al.*, 1995). Cole *et al.* (1999) suggested that herbicides, such as simazine and atrazine, were very toxic to macrophytes. The evidence suggests that in general red algae are very sensitive to synthetic chemicals. Intolerance of *Chondrus crispus* is therefore recorded as high.

Cole *et al.* (1999) suggested that herbicides were (not surprisingly) very toxic to algae and macrophytes. Hoare & Hiscock (1974) noted that with the exception of *Phyllophora* species, all red algae including encrusting coralline forms, were excluded from the vicinity of an acidified halogenated effluent discharge in Amlwch Bay, Anglesey and that intertidal populations of *Corallina officinalis* occurred in significant amounts only 600m east of the effluent. Chamberlain

(1996) observed that although *Lithophyllum incrustans* was quickly affected by oil during the *Sea Empress* spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area.

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
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No evidence was found to assess this pressure at the benchmark. Algae bioaccumulate radionuclides (with extent depending on the radionuclide and the algae species). A study in France found that *Chondrus crispus* was capable of absorbing a large number of artificial radioactive elements and that this had consequences considering the exploitation of this species as a harvestable resource (Cosson *et al.*, 1984). However, no information was found concerning the actual effects of radionuclide on *Chondrus crispus*.

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
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This pressure is **Not assessed**.

De-oxygenation	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR
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The effects of reduced oxygenation on algae are not well studied. Plants require oxygen for respiration, but this may be provided by production of oxygen during periods of photosynthesis. Lack of oxygen may impair both respiration and photosynthesis (see review by Vidaver, 1972). A study of the effects of anoxia on a red algae found within this biotope, *Delesseria sanguinea*, revealed that specimens died after 24 hours at 15°C but that some survived at 5°C (Hammer, 1972). No evidence is available to make an intolerance assessment for the key characterizing species.

Nutrient enrichment	High Q: High A: Low C: Medium	High Q: High A: High C: High	Not sensitive Q: High A: Low C: Medium
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Although *Chondrus crispus* and *Polyides rotunda* and other characterizing species may be out-competed by faster growing or ephemeral green and red algal species where nutrient enrichment is extensive or prolonged (Johansson *et al.*, 1998), the levels of scour and sand abrasion are likely to limit the growth of competing species as these tend to be thin and less robust.

Short-term experiments with low levels of nutrient enrichment showed little impacts on red algal turfs. Atalah & Crowe (2010) added nutrients to rockpools occupied by a range of algae including encrusting corallines, turfs of *Mastocarpus stellatus*, *Chondrus crispus* and *Corallina officinalis* and green and red filamentous algae. Nitrogen and phosphorous enhancement was via the addition of fertilisers, as either 40 g/litre or 20 g/litre. The treatments were applied for seven months and experimental conditions were maintained every two weeks. The experimental treatments do not directly relate to the pressure benchmark or biotope type but indicate some general trends in sensitivity. Nutrients had no significant effect on the cover of crustose coralline algae or the cover of red turfing algae. However, the cover of green filamentous algae increased only where grazers

were removed (Atalah & Crowe, 2010).

Over geological timescales periods of increased nutrient availability have experienced increases in the distribution of crustose coralline species at the expense of corals (Littler & Littler, 2013), suggesting that this group have some tolerance for enhanced nutrient levels. Overall, Littler & Littler (2013) suggest that corallines as a group can tolerate both low and elevated levels of nutrients. The crusting coralline *Lithophyllum incrustans* were present at sites dominated by *Ulva* spp. in the Mediterranean exposed to high levels of nutrient enrichment from domestic sewage (Arévalo *et al.*, 2007).

Sensitivity assessment. The pressure benchmark is relatively protective and may represent a reduced level of nutrient enrichment in previously polluted areas. Due to the tolerance of high levels of nutrient input demonstrated generally by red algal turfs, resistance to this pressure is assessed as 'High' and resilience as 'High' so that the biotope is assessed as 'Not sensitive'.

Organic enrichment

High

Q: Low A: NR C: NR

High

Q: High A: High C: High

Not sensitive

Q: Low A: Low C: Low

Where 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 crusting coralline *Lithophyllum incrustans* were present at sites dominated by *Ulva* spp. in the Mediterranean exposed to high levels of organic pollution from domestic sewage (Arévalo *et al.*, 2007). As turf forming algae, including the red algal turf trap large amounts of sediment the turf itself is not considered sensitive to sedimentation. The turfs probably host a variety of associated species and deposit feeders amongst these would be able to consume inputs of organic matter.

In a recent review, assigning species to groups based on tolerances to organic pollution, the anemone *Urticina felina* was 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).

Sensitivity assessment. Based on resistance to sedimentation, exposure to wave action, and the dominance of red algal turfs in areas subject to sewage inputs, resistance is assessed as 'High' and resilience as 'High' (by default). The biotope is therefore considered to be 'Not sensitive' to this pressure at the benchmark.

A Physical Pressures

Resistance

None

Q: High A: High C: High

Resilience

Very Low

Q: High A: High C: High

Sensitivity

High

Q: High A: High C: High

Physical loss (to land or freshwater habitat)

All marine habitats and benthic species are considered to have a resistance of 'None' to this pressure and to be unable to recover from a permanent loss of habitat (resilience is 'Very Low'). Sensitivity within the direct spatial footprint of this pressure is therefore 'High'. Although no

specific evidence is described confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

Physical change (to another seabed type)

None

Q: Low A: NR C: NR

Very Low

Q: Low A: NR C: NR

High

Q: Low A: Low C: Low

This biotope is characterized by a hard rock substratum that is overlain or periodically exposed to, a layer of coarse sand. Removal of the bedrock would remove the attachment surface for the red algal turf that characterizes this biotope and the absence of sand may allow colonisation of less scour-tolerant species, significantly altering the character of the biotope.

Artificial hard substratum may also differ in character from natural hard substratum, so that replacement of natural surfaces with artificial may lead to changes in the biotope through changes in species composition, richness and diversity (Green *et al.*, 2012; Firth *et al.*, 2014) or the presence of non-native species (Bulleri & Aioldi, 2005). The key characterizing species, *Chondrus crispus* readily colonised artificial settlement plates and by the end of the experiment was the dominant species on plates (Harlin & Lindbergh, 1977). *Chondrus crispus* were however significantly more abundant on the substratum with the largest particles (1-2 mm) and only a few individuals were found on the smooth surface, demonstrating that artificial smooth surfaces may not provide an optimal habitat.

In the absence of hard substratum crustose corallines can propagate as free-living rhodolith nodules and can form extensive subtidal habitats (Littler & Little, 2013). However, these biogenic reefs are not analogous to this habitat type.

Sensitivity assessment. Based on the loss of suitable habitat, biotope resistance is assessed as 'None' and recovery is assessed as 'Very Low' as the change at the pressure benchmark is permanent. Sensitivity is therefore 'High'.

Physical change (to another sediment type)

Low

Q: Low A: NR C: NR

Very Low

Q: High A: High C: High

High

Q: Low A: Low C: Low

Generally this pressure is considered to be 'Not relevant' to biotopes occurring on bedrock. However, as this biotope is often overlain by sands or exposed to shifting sands this pressure is assessed. The sand covering and scour is an important factor supporting development and maintenance of this biotope. Removal of sands may allow species with less scour tolerance to colonize altering the character of the biotope. Siltation by finer sediments may have less impact but may lead to subtle changes and changes such as anoxia at the bedrock/sediment interface may lead to removal or damage of holdfasts and bases. A change to coarser gravels, pebbles and cobbles would increase the degree of abrasion where these are mobile and this may also remove the red algal turf.

Sensitivity assessment. A change in the character of the overlying sediment may alter the character of the biotope. Resistance is, therefore, assessed as 'Low' and resilience is Very low (the pressure is a permanent change), so that the biotope is considered to have 'High' sensitivity to this pressure.

Habitat structure changes - removal of substratum (extraction)

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

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

Medium

Q: High A: High C: Medium

High

Q: High A: High C: High

Low

Q: High A: High C: Medium

The red algal turf that characterizes this biotope has some resistance to abrasion as these species persist where scour rates are high from resuspension and transport of sand particles. Little empirical evidence was found to support this assessment.

Chondrus crispus is flexible (Dixon & Irvine, 1977) and would be expected to be relatively resistant to physical abrasion. Indeed, Worm & Chapman (1998) suggested that