Green seaweeds (*Ulva* spp. and *Cladophora* spp.) in shallow upper shore rockpools

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Green seaweeds (*Enteromorpha* spp. and *Cladophora* spp.) in upper shore rockpools
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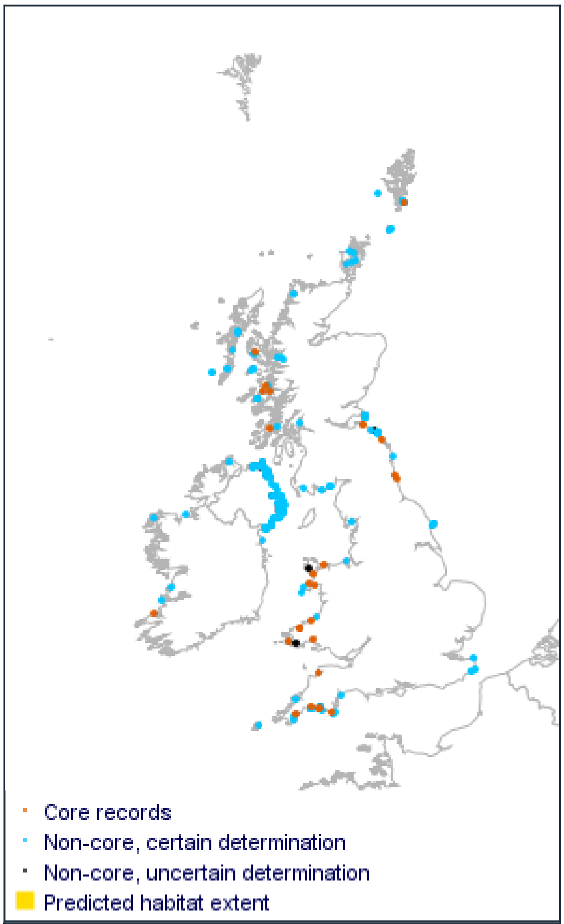

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Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Dr Heidi Tillin & Georgina Budd **Refereed by** This information is not refereed.

Summary

UK and Ireland classification

EUNIS 2008	A1.421	Green seaweeds (*Enteromorpha* spp. and *Cladophora* spp.) in shallow upper shore rockpools
JNCC 2015	LR.FLR.Rkp.G	Green seaweeds (*Ulva* spp. and *Cladophora* spp.) in shallow upper shore rockpools
JNCC 2004	LR.FLR.Rkp.G	Green seaweeds (*Enteromorpha spp*. and *Cladophora spp*.) in shallow upper shore rockpools
1997 Biotope	LR.LR.Rkp.G	Green seaweeds (*Enteromorpha spp*. and *Cladophora spp*.) in upper shore rockpools

Description

Rockpools in the littoral fringe or upper eulittoral zone subject to widely fluctuating temperatures and salinity are characterized by ephemeral green alga of the genus *Ulva*, along with *Cladophora* spp. and *Ulva lactuca*. Due to the physical stress imposed on these upper shore pools, grazing molluscs such as the limpet Patella vulgata and the winkles *Littorina littorea* and *Littorina saxatilis* are generally in lower abundance than eulittoral pools, allowing the green seaweeds to proliferate under reduced grazing pressures. The bright orange copepod *Tigriopus fulvus* is tolerant of large salinity fluctuations and may occur in large numbers in these upper shore pools, along with gammarid amphipods (JNCC, 2015).

Depth range

Upper shore

Additional information

No text entered.

Listed By

- none -

Further information sources

Search on:

G G JNCC

Habitat review

Ecology

Ecological and functional relationships

In rockpools high on the shore, the familiar flora and fauna of rockpools is lost, the community becomes greatly depleted consisting of forms that are highly adapted to the rigorous and almost estuarine conditions (Lewis, 1964) as physical factors are the dominant structuring force.

- Amongst the fauna, crustaceans predominate. Large populations (720 x 10^3/m□) of the copepod *Tigriopus fulvus* can occur in upper shore rockpools densely covered by the green alga *Ulva intestinalis* (Goss-Custard *et al*., 1979). *Tigriopus fulvus* is remarkably tolerant of extremes of salinity and temperature (Ranade, 1957). Ranade (1957) stated that *Tigriopus fulvus* could live normally between salinities of 4-90 psu. In laboratory experiments, Goss-custard *et al*. (1979) found the species to survive for 15 days in salinities ranging from 42-90 psu, but died after 84 hours in distilled water, and sank to the bottom in salinities greater than 90 psu in a state of apparent death. However, if transferred to seawater (35 psu) after some hours it could recover. In tests with a slowly rising temperature, the death point was 32°C at a salinity of 34 psu, but this rose to 41.8°C at a salinity of 90 psu. Thus high salinities enable *Tigriopus fulvus* to withstand high temperature, a feature useful for a species living in pools in a zone where insolation and evaporation may be considerable. Despite the instability of the high shore rockpool as a habitat, the copepod benefits from the lower abundance of predators, that are in greater abundance in lower shore rockpools (Dethier, 1980).
- *Ulva intestinalis* provides shelter for the orange harpacticoid copepod, *Tigriopus brevicornis*, and the chironomid larva, *Halocladius fucicola* (McAllen, 1999). *Ulva intestinalis* is often the only seaweed found in supralittoral rockpools, and the copepod and chironomid species utilize the hollow thallus of *Ulva intestinalis* as a moist refuge from desiccation when the rockpools completely dry out. Several hundred individuals of *Tigriopus brevicornis* have been observed in a single thallus of *Ulva intestinalis* (McAllen, 1999).
- There are three major sources of food available to the fauna of high shore rockpools: the thalli of *Ulva* sp. and other macroalgae, the epiphytic micro-organisms attached to the surface of the *Ulva* and the micro-organisms associated with the substratum (Clark, 1968).
- The distribution of grazers, *Melarhaphe neritoides* and *Littorina saxatilis* extends into the upper littoral fringe, the former feeding on micro-algae and lichens, the latter grazing on macroalgae and the microalgal film on the rocks. Both winkles favour crevices, especially in dry weather, from which they can forage, but owing to the physical stresses of the upper shore, grazing molluscs are generally lower in abundance than in eulittoral pools allowing green algae to proliferate as a result of reduced grazing pressure.
- A band of yellow and grey lichens (LR.YG) is usually found immediately above the zone of *Verrucaria maura* which occurs in this biotope. The fauna of the LR.YG biotope may extend into the LR.G biotope to exploit the lichen. For instance, lichens are fed on by fungivorous Cryptostigmata and other acarid mites and potentially by some lichen dwelling tardigrades (Gerson & Seaward, 1977) and the bristle tail *Petrobius maritimus* (Joosse, 1976), while rotifers have been reported to consume lichen ascospores (Gerson & Seaward, 1977).

Seasonal and longer term change

Rockpools constitute a distinct environment for which physiological adaptations by the flora and fauna may be required (Lewis, 1964). Physico-chemical parameters within rockpools fluctuate dramatically as a consequence of prolonged separation from the main body of the sea (Huggett & Griffiths, 1986). In general, larger and deep rockpools low on the shore tend to correspond to the sublittoral habitat with a more stable temperature and salinity regime. In contrast, small and shallow pools are especially influenced by insolation, air temperature and rainfall, the effects of which become more significant towards the high shore, where pools may be isolated from the sea for a number of days or weeks (Lewis, 1964).

- Weather conditions exert a considerable influence on temperature and salinity. Water temperature in pools follows the temperature of the air more closely than that of the sea. In summer, shallow pools or the surface waters of deeper pools are warmer by day, but may be colder at night, and in winter may be much colder than the sea (Pyefinch, 1943). In deeper pools, the vertical temperature gradation usually present in summer, reverses during winter owing to density stratification, so that ice may form (Naylor & Slinn, 1958).
- High air temperatures cause surface evaporation of water from pools, so that salinity steadily increases, especially in pools not flooded by the tide for several days. Alternatively, high rainfall will reduce pool salinity or create a surface layer of brackish/nearly freshwater for a period. However, the extent of temperature and salinity change is affected by the frequency and time of day at which tidal inundation occurs. If high tide occurs in early morning and evening the diurnal temperature follows that of the air, whilst high water at midday suddenly returns the temperature to that of the sea (Pyefinch, 1943). Heavy rainfall, followed by tidal inundation can cause dramatic fluctuations in salinity, and values ranging from 5-30 psu have been recorded in a period of 24 hours (Ranade, 1957). Rockpools in the supralittoral, littoral fringe and upper eulittoral are liable to gradually changing salinities followed by days of fully marine or fluctuating salinity at times of spring tide (Lewis, 1964).
- Other physico-chemical parameters in rockpools demonstrate temporal change. The biological community directly affect oxygen concentration, carbon dioxide concentration and pH, and are themselves affected by changes in the chemical parameters. Throughout the day, algae photosynthesize and produce oxygen, the concentration of which may rise to three times its saturation value, so that bubbles are released. During photosynthesis algae absorb carbon dioxide and as concentrations fall, the pH rises. pH values >9 were recorded in rockpools on the Isle of Cumbrae (Morris & Taylor, 1983). At night changes occur in the opposite direction. Respiration utilizes much of the available oxygen and pH decreases.

Fluctuations especially in the abundance of green seaweeds is likely owing to the marked changes in salinity and temperature during the year. For instance, surface layers of *Ulva* may be bleached in the summer.

Habitat structure and complexity

Rockpools vary greatly in their physical features. Pools in bedrock may be shallow and well-lit or deep and shaded with overhanging sides and vertical surfaces. Algae growing within provide additional surface for colonization and for shelter. There is also a tendency for loose substrata (sand, stones, rocks) to accumulate in pools, the instability of which may cause abrasion and affect species diversity. Amongst rockpools, deep crevices may be found, around the entrance of which small mussels may cluster. Crevices also support their own specialized fauna with many airbreathing arthropods such as centipedes, millipedes, beetles, pseudoscorpions and primitive onchidellid pulmonates (see Lewis, 1964).

Productivity

Macroalgae and the microbial film of bacteria, blue-greens, diatoms, fungi and protozoans are the primary producers in this biotope. Accumulations of algal debris are also likely in high shore rockpools and such detrital material contributes to overall productivity. Information specific to the community was not found, but Workman (1983) gave an estimate of primary production by microalgal films on the high shore in the British Isles to be in the region of 60 g C/m^2/yr, much of which will be utilized directly by grazers.

Recruitment processes

Flora:
Rockpools in the supralittoral, littoral fringe or upper eulittoral which are subject to variable salinity and widely fluctuating temperatures are characterized by the ephemeral green alga *Ulva* spp. or the filamentous green alga *Cladophora* spp.
Species of the genus *Ulva* are rapidly growing opportunists, favoured by the frequency and speed of their reproduction. The short lived plants reach maturity at a certain stage of development rather than relying on an environmental trigger. *Ulva intestinalis* can be found in reproductive condition at all times of the year, but maximum development and reproduction occur during the summer months especially towards the northern end of the distribution of the species (Burrows, 1991). The life history consists of an isomorphic (indistinguishable except for the type of reproductive bodies produced) alternation between haploid gametophytic and diploid sporophytic generations, but can be modified by environmental conditions (Burrows, 1959; Moss & Marsland, 1976; Reed & Russell, 1978).
The haploid gametophytes of *Ulva* produce enormous numbers of biflagellate motile gametes which cluster and fuse to produce a sporophyte (diploid zygote). The sporophyte matures and produces by meiosis large numbers of quadriflagellate zoospores that mature as gametophytes, and the cycle is repeated. Both gametes and spores may be released in such quantities into rock pools or slack water that the water mass is coloured green (Little & Kitching, 1996). Together spores and gametes are termed 'swarmers'. Swarmers are often released in relation to tidal cycles, with the release being triggered by the incoming tide as it wets the thallus. However, the degree of release is usually related to the stage of the spring/neap tidal cycle, so allowing regular periodicity and synchronization of reproduction (Little & Kitching, 1996). Christie & Evans (1962) found that swarmer release of *Ulva intestinalis* from the Menai Straits, Wales, peaked just before the highest tides of each neap-spring cycle. Mobility of swarmers belonging to *Ulva intestinalis* can be maintained for as long as 8 days (Jones & Babb, 1968). Algae such as *Ulva intestinalis* tend to have large dispersal shadows, with propagules being found far from the nearest adult plants, e.g. 35 km (Amsler & Searles, 1980).
Information on the ecology of reproduction and propagation of the genus *Cladophora* is limited. Reproduction is asexual, and achieved by the release of quadriflagellate zoospores and biflagellate isogametes formed in the terminal cells of fronds. The life history consists of an isomorphic (indistinguishable except for the type of reproductive bodies produced) alternation of gametophyte and sporophyte generations, the plants are dioecious (Burrows, 1991). Both zoospores and gametes can be found at most times of the year. Archer (1963) was unable to find any correlation between the time of reproduction, the state of tide or environmental conditions. Most species of *Cladophora* attach to the substratum by multicellular, branching rhizoids (van den Hoek, 1982); these basal holdfasts may serve as resistant structures from which new growths can

arise.
Fauna:
Fraser (1936) describes the ecology and life-history of the copepod *Tigriopus fulvus*. The species mates throughout the year. Females of the species release a sex pheromone promoting sexual recognition and attraction in males (Lazzaretto *et al.*, 1994). Females brood the fertilized eggs which may be released between 5-15 days after the appearance of the female's egg sac, the time being shorter in summer and longer in winter. A single female may produce numerous juveniles from several egg sacs without further mating. From the time of hatching a juvenile attains an adult form and the ability to reproduce in about two months (Fraser, 1936).
Internal fertilization occurs in all species of winkle (littorinids). *Melarhaphe neritoides* releases its eggs into the plankton, whilst the female *Littorina saxatilis* broods its eggs which hatch as live young. Although animals with planktonic larvae have a greater dispersive ability than those with direct development, the production of crawling, live young from egg capsules or brood pouches reduces reproductive losses and permits exploitation of locally favourable conditions. It can also lead to inbreeding and genetic isolation of populations. For instance, owing to dispersion in the plankton the population of *Melarhaphe neritoides* is genetically homogenous, which is reflected in their uniform colour. *Littorina saxatilis*, which bears live young and are variable in size and colour (Hawkins & Jones, 1992).

Time for community to reach maturity

To recruit, grow and reproduce in the unpredictable environment of high shore rockpools, the flora and fauna within need to be capable of rapid recruitment, early maturation and rapid growth in order to exploit the habitat, thus it is likely that the community would be considered mature in terms of species present and capable of reproduction within a few months.
For example, with the exception of *Cladophora rupestris* whose turfs may persist for many years, the macroalgal species, e.g. *Ulva*, *Monostroma* and *Prasiola stipitata* which are characteristic of this biotope are seasonal and short lived (ephemeral) algae, which recruit rapidly to available substrata. For instance, the thalli of *Ulva intestinalis*, which arise from spores and zygotes, grow within a few weeks into thalli that reproduce again, and the majority of the cell contents are converted into reproductive cells. The species is also capable of dispersal over a considerable distance. For instance, Amsler & Searles (1980) showed that swarmers of a coastal population of *Ulva* reached exposed artificial substrata on a submarine plateau 35 km away. *Ulva* is amongst the first multicellular algae to appear on substrata that have been cleared following a disturbance, e.g. following the *Torrey Canyon* oil spill in March 1967, species of the genus *Ulva* rapidly recruited to areas where oil had killed the herbivores that usually grazed on them, so that a rapid greening of the rocks (owing to a thick coating of macroalgae) was apparent by mid-May (Smith, 1968).

Additional information

No text entered.

Preferences & Distribution

Habitat preferences

Depth Range	Upper shore
Water clarity preferences	Data deficient
Limiting Nutrients	Nitrogen (nitrates), Phosphorus (phosphates)

Salinity preferences	Full (30-40 psu), Variable (18-40 psu)
Physiographic preferences	
Biological zone preferences	Supralittoral, Upper eulittoral
Substratum/habitat preferences	Bedrock, Rockpools
Tidal strength preferences	No information
Wave exposure preferences	Exposed, Moderately exposed, Sheltered, Very exposed
Other preferences	

Additional Information

No text entered.

Species composition

Species found especially in this biotope

- *Tigriopus fulvus*

Rare or scarce species associated with this biotope

-

Additional information

None entered

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The characteristic elements of this biotope were defined based on the description by Connor *et al.* (2004). This is a rock pool biotope found high on shores in the littoral fringe or upper eulittoral zone. The biotope is subject to widely fluctuating temperatures and salinity and is characterized by ephemeral green alga of the genus *Ulva*, including *Ulva lactuca* along with *Cladophora* spp. including *Cladophora rupestris*. The genus *Ulva* currently contains 23 taxonomically accepted species (Guiry & Guiry, 2015), although the genus is now more generally accepted as a synonym for *Ulva* (Hayden *et al.*, 2003). Identification of *Ulva* to the species level can be problematic and in some instances species can only be distinguished by experts or by genetic analysis and understanding of the taxonomic relationships between green algal species and higher taxonomic levels is rapidly evolving.

Due to the physical stress imposed on these upper shore pools, grazing molluscs such as the limpet *Patella vulgata* and the winkles *Littorina littorea* and *Littorina saxatilis* are generally in lower abundance than eulittoral pools, allowing the green seaweeds to proliferate under reduced grazing pressures. The bright orange copepod *Tigriopus fulvus* is tolerant of large salinity fluctuations and may occur in large numbers in these upper shore pools, along with gammarid amphipods.

The sensitivity assessments are largely based on the typical characterizing species *Ulva lactuca*, *Ulva intestinalis* (formerly *Enteromorpha intestinalis*) and *Cladophora spp.* Due to the high levels of stress, the biotope is species poor and animals that do occur in the biotope are found in low abundances. The biotope is maintained by environmental stressors, common to rockpools high on the shore, including widely fluctuating temperature and salinity and these factors are considered within the sensitivity assessments where they may be altered by the pressure. As the low abundance of the grazers *Patella vulgata* and winkles *Littorina littorea* or *Littorina saxatilis*, allows the green algae to thrive, their sensitivity is discussed but not specifically considered within the biotope assessments. However, where the pressure may allow these species to increase in abundance then this is indicated as it may alter the character of the biotope.

Resilience and recovery rates of habitat

The *Ulva* spp. and *Cladophora* spp. that characterize this biotope are classified as opportunistic species that are able to rapidly colonize newly created gaps across a range of sediment types, shore heights, wave exposures and salinity regimes. The life history characteristics that support this opportunism are the broad tolerances for a wide range of conditions (Vermaat & Sand-Jensen, 1987) and high growth and reproduction rates. *Ulva* sp. release zoospores and gametes (collectively called swarmers) to the water column in high numbers. *Ulva* spp. can form the swarmers from normal thallus cells that are transformed into reproductive tissue rather than having to produce specialised reproductive structures (Lersten & Voth, 1960), so that a significant portion of the macroalga's biomass is allocated to the formation of zoospores and gametes (Niesenbaum, 1988). *Ulva* sp. have extended reproduction periods (Smith, 1947) and swarmers are capable of dispersal over a considerable distance. For instance, Amsler & Searles (1980) showed that swarmers of a coastal population of *Ulva* (as *Enteromorpha*) reached exposed artificial substrata on a submarine plateau 35 km away. In addition to recruitment by swarmers, new growth of *Cladophora rupestris* may arise from the resistant multicellular branching rhizoids (van den Hoek, 1982) that may remain in situ.

The supply of swarmers in vast numbers to the coastline (Niesenbaum, 1988) is reflected in the fast recovery rates of this genus. *Ulva intestinalis* is amongst the first multicellular algae to appear on substrata that have been cleared following a disturbance, e.g. following the Torrey Canyon oil spill in March 1967, species of the genus *Ulva* rapidly recruited to areas where oil had killed the herbivores that usually grazed on them, so that a rapid greening of the rocks (owing to a thick coating of *Ulva* spp.) was apparent by mid-May (Smith, 1968). The rapid recruitment of *Ulva* spp. to areas cleared of herbivorous grazers was also demonstrated by Kitching & Thain (1983). Following the removal of the urchin *Paracentrotus lividus* from areas of Lough Hyne, Ireland, *Ulva* grew over the cleared area and reached a coverage of 100% within one year.

Recovery of the copepod *Tigriopus fulvus* would be expected to be rapid (presuming a residual or localized population remained from which to recruit) as the species is in reproductive condition all year round and reaches sexual maturity within two months. It also can produce more than one brood from one fertilization. Other species that are associated with this biotope, including the limpet *Patella vulgata* and littorinds generally have slower recovery rates than *Ulva* spp. due to episodic recruitment and slower growth. Where individuals are removed from a small area, adult limpets and *Littorina saxatilis* may recolonize from surrounding patches of habitat where these are present. The barnacles and limpets and the winkle *Littorina littorea* are common, widespread species that spawn annually producing pelagic larvae that can disperse over long distances. It is therefore likely that adjacent populations will provide high numbers of larvae, although recruitment may be low due to habitat unsuitability and the presence of dense *Ulva* spp. preventing settlement on rock surfaces. *Littorina saxatilis* however brood young and do not have a pelagic life stage, recovery will therefore depend on the presence of adults in close proximity to impacted areas. As the associated species occur at low densities when they are present, their absence will not substantially alter the character of the biotope. They are therefore, not specifically considered within the resilience assessments as the biotope can be considered to have recovered before these species re-establish. Indeed, as limpets and littorinds graze on the macroalgae characterizing the biotope and can prevent blooms of *Ulva* spp. forming (Robles, 1982, Albrecht, 1998), their presence in large numbers would alter the character of this biotope.

Resilience assessment. The high recovery potential of the *Ulva* spp. and *Cladophora* spp. that characterize this biotope, mean that recovery is assessed as 'High' (within 2 years) for any level of perturbation (where resistance is 'None', 'Low', 'Medium' or 'High'. Depending on the season of the impact and level of recovery, the biotope may have recovered within less than six months.

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

Hydrological Pressures

	Resistance	Resilience	Sensitivity

Temperature increase (local)	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

Intertidal species are exposed to extremes of high and low air temperatures during periods of emersion. They must also be able to cope with sharp temperature fluctuations over a short period of time during the tidal cycle. In winter air temperatures are colder than the sea, conversely in summer air temperatures are much warmer than the sea. Species that occur in this intertidal biotope are therefore generally adapted to tolerate a range of temperatures. In general, the water temperature of rockpools follows that of the air more closely than that of the sea, and throughout any 24 hour period, dramatic changes in temperature may be observed. For instance, Pyefinch (1943) plotted diurnal changes in a pool lying above mean high water during July. When the pool was out of contact with the sea, water temperature increased by 5°C from 14 to 19°C over a three hour period and decreased suddenly to 14°C within 1.5 hours when the incoming tide reached it. Hence, the community that inhabits such environments needs to be especially tolerant of acute temperature changes.

The key characterizing *Ulva* spp. are distributed globally and occur in warmer waters than those surrounding the UK suggesting that they can withstand increases in temperature at the pressure benchmark. *Ulva* spp. are characteristic of upper shore rock pools, where water and air temperatures are greatly elevated on hot days. Empirical evidence for thermal tolerance to anthropogenic increases in temperature is provided by the effects of heated effluents on rocky shore communities in Maine, USA. *Ascophyllum* and *Fucus* were eliminated from a rocky shore heated to 27-30°C by a power station whilst *Ulva intestinalis* (as *Enteromorpha intestinalis*) increased significantly near the outfall (Vadas *et al.*, 1976) and Lüning (1984) reported that Cladophora rupestris could survive exposure to temperatures in the range 0 - 28°C for at least a week.

The copepod *Tigriopus fulvus* is more tolerant of high temperatures at higher salinities . At a salinity of 34 psu, the death point of *Tigriopus fulvus* is reached at 32°C (Goss-Custard et al.,1979). Limpets, *Patella vulgata* and littorinids may occur at low densities in this biotope. Laboratory studies suggest that adults of these species can tolerate temperature increases.   The median upper lethal temperature limit in laboratory tests on *Littorina littorea*, *Littorina saxatilis* was approximately 35°C (Davenport & Davenport, 2005). *Patella vulgata* can also tolerate high temperatures. The body temperature of *Patella vulgata* can exceed 36°C in the field, (Davies, 1970); adults become non-responsive at 37-38°C and die at temperatures of 42°C (Evans, 1948). Although adults may be able to withstand acute and chronic increases in temperature at the pressure benchmark, increased temperatures may have sub-lethal effects on the population by impacting the success of reproduction phases. The distribution of *Patella vulgata* is 'northern' with their range extending to the Arctic circle. Populations in the southern part of England are relatively close to the southern edge of their geographic range.   Increased temperatures may alter spawning cues and reproduction success in *Patella vulgata* populations. Observations suggest that spawning is initiated in autumn storms with greater wave action when seawater temperatures drop below 12°C (Bowman 1985; Bowman & Lewis; 1986; LeQuesne, 2005). In Northern Portugal, warming seas appear to be linked to a shortening of the reproductive period and the lack of multiple spawning events in *Patella vulgata* and other northern species (Ribeiro *et al.*, 2009).

Sensitivity assessment. Adults of the associated species *Patella vulgata* and *Littorina* spp. are considered likely to be able to tolerate an acute or chronic increase in temperature at the pressure benchmark, although the timing of acute and chronic increases would alter the degree of impact and hence sensitivity. An acute change occurring on the hottest day of the year and exceeding thermal tolerances would lead to mortality. Sensitivity of *Patella vulgata* to longer-term, broad-scale perturbations would potentially be greater due to effects on reproduction but these changes may lead to species replacements and are not considered to significantly affect the character of the biotope. *Ulva* spp., are the key characterizing elements that define this biotope and are considered to tolerate increases in temperature at the pressure benchmark. Biotope resistance is, therefore, assessed as 'High' and recovery as 'High' (by default) so that the biotope is assessed as 'Not sensitive'.

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

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

The key species characterizing this biotope, *Ulva intestinalis* and *Ulva lactuca* are found in Arctic regions (Guiry & Guiry, 2015 and references therein), *Ulva* sp. (as *Enteromorpha*) were reported to be tolerant of a temperature of -20°C (Kylin, 1917). Vermaat & Sand-Jensen (1987) found that rapid deep freezing of Ulva lactuca collected in Roskilde Fjord, Denmark killed the plants. However, individuals from the same area when collected from frozen ice, survived and resumed growth, the plants are able to survive more gradual natural freezing (Vermaat & Sand-Jensen, 1987).

Limpets, *Patella vulgata* and littorinids may occur at low densities in this biotope. Laboratory studies suggest that adults of these species can tolerate temperature decreases. The median lower lethal temperature tolerances of *Littorina saxatilis* and *Littorina littorea* were -16.4 and -13 °C for individuals collected in winter from Great Cumbrae, Scotland was -14.6 °C (Davenport & Davenport, 2005). In experiments *Littorina littorea* were able to tolerate temperatures down to -8 °C for 8 days (Murphy, 1983). In colder conditions an active migration may occur down the shore to a zone where exposure time to the air (and hence time in freezing temperatures) is less. The limpet, *Patella vulgata* can also tolerate long periods of exposure to the air and can consequently withstand wide variations in temperature. Adults are also largely unaffected by short periods of extreme cold. Ekaratne & Crisp (1984) found adult limpets continuing to grow over winter when temperatures fell to -6°C, and stopped only by still more severe weather. However, loss of adhesion after exposure to -13°C has been observed with limpets falling off rocks and therefore becoming easy prey to crabs or birds (Fretter & Graham, 1994). In the very cold winter of 1962-3 when temperatures repeatedly fell below 0 °C over a period of 2 months large numbers of *Patella vulgata* were found dead (Crisp, 1964). Periods of frost may also kill juvenile *Patella vulgata*, resulting in recruitment failures in some years (Bowman & Lewis, 1977).

The distribution of *Patella vulgata* is 'northern' with their range extending to the Arctic circle. Over their range they are therefore subject to lower temperatures than in the UK, although distributions should be used cautiously as an indicator of thermal tolerance (Southward *et al.*, 1995).

Sensitivity assessment. The presence of *Ulva* spp. in arctic regions and the freezing tolerances reported by Vermaat & Sand-Jensen (1987) indicate that *Ulva* spp., would have ‘High’ resistance to decreases in temperature at the acute and chronic benchmarks. The wide temperature tolerance range of *Patella vulgata* and *Littorina saxatilis* suggest that the acute and chronic decreases in temperature described by the benchmark would not lead to mortalities.. Based on the characterizing and associated species, this biotope is considered to have ‘High’ resistance and ‘High resilience (by default) to this pressure and is therefore considered to be ‘Not sensitive’. The timing of changes and seasonal weather could result in greater impacts on species. An acute decrease in temperature coinciding with unusually low winter temperatures may exceed thermal tolerances and lead to mortalities of the associated species although this would not alter the character of the biotope.

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

The biotope typically experiences conditions of full (30-40 psu) or variable (reduced, owing to freshwater runoff) salinity. The key characterizing *Ulva* species can survive the hypersaline conditions in supralittoral rockpools subjected to evaporation and is considered to be a very euryhaline species, tolerant of extreme salinities ranging from 0 psu to 136 psu (Reed & Russell, 1979). Some variations in salinity tolerance between populations of *Ulva intestinalis* have been found, however, suggesting that plants have some adaptation to the local salinity regime. Alströem-Rapaport *et al*., (2010), found that in the brackish Baltic Sea, *Ulva intestinalis* uses a variety of reproductive modes which was considered to partly explain the high rates of colonisation and adaptability of the species.

Reed & Russell (1979) found that the ability to regenerate from cut thalli varied according to the salinity conditions of the original habitat, and that the pattern of euryhalinity in parental material and offspring was in broad agreement (Reed & Russell (1979). Eulittoral zone material showed decreased percentage regeneration in concentrated seawater: 51, 68, 95, 102 & 136 psu) when compared to littoral fringe populations of *Ulva intestinalis* (as *Enteromorpha intestinalis*). Increased salinity is most likely to occur in the region of the littoral fringe and supralittoral zone and specimens from these areas were able to tolerate very high salinities, a significant decrease in regeneration only being recorded after exposure to concentrated seawater (102 psu and 136 psu) for > 7 days (Reed & Russell, 1979).

Sensitivity assessment. The characterizing *Ulva* species and the associated species are considered able to tolerate increases in salinity. Based on reported distributions and the results of experiments to assess salinity tolerance thresholds and behavioural and physiological responses it is considered that *Ulva* spp. and the associated littorinids and limpets would tolerate a change in salinity from variable or reduced to full and some salinity increases above full salinity. As the associated species occur only in low numbers and do not characterize the biotope the sensitivity assessment is based on the *Ulva* species alone. Biotope resistance is assessed as 'High' and resilience as 'High', based on no effect to recover from and the biotope is considered to be 'Not sensitive'.

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

The biotope typically experiences conditions of full (30-40 psu) or variable (reduced, owing to freshwater runoff) salinity. The key characterizing *Ulva* species are considered to be a very euryhaline, tolerant of extreme salinities ranging from 0 psu to 136 psu (Reed & Russell, 1979). Some variations in salinity tolerance between populations of *Ulva intestinalis* have been found, however, suggesting that plants have some adaptation to the local salinity regime. Alströem-Rapaport *et al*., (2010), found that in the brackish Baltic Sea, *Ulva intestinalis* uses a variety of reproductive modes which was considered to partly explain the high rates of colonisation and adaptability of the species. Reed & Russell (1979) found that the ability to regenerate from cut thalli varied according to the salinity conditions of the original habitat, and that the pattern of euryhalinity in parental material and offspring was in broad agreement (Reed & Russell (1979). For example; eulittoral zone material showed decreased percentage regeneration in all salinities (dilute: 0, 4.25, 8.5, 17 & 25.5 psu, and concentrated seawater: 51, 68, 95, 102 & 136 psu) except 34 psu, when compared to littoral fringe populations of *Ulva intestinalis* (as *Enteromorpha intestinalis*). None of the eulittoral zone material was able to regenerate in freshwater or concentrated seawater, whilst littoral fringe and rock pool material was able to do so.

Reduced salinity has also been reported to affect the growth rate of *Ulva intestinalis*. Martins *et al*. (1999) observed that in years with high precipitation and significant increase of freshwater runoff to the Mondego estuary (west Portugal), that *Ulva intestinalis* (as *Enteromorpha intestinalis*) failed to bloom. In the laboratory, the growth rate of *Ulva intestinalis* was measured against a range of salinities, from 0 to 32 psu. *Ulva intestinalis* showed the lowest growth rates at extremely low salinity values (less than or equal to 3 psu), and for salinity less than or equal to 1 psu, the algae died. Growth rates at a salinity lower than 5 psu and higher than 25 psu were also low, in comparison to growth between a salinity of 15 and 20 psu, where *Ulva intestinalis* showed the highest growth rates. Kamer & Fong (2001) found that high nitrogen enrichment mitigated the negative effects that reduced salinity had on *Ulva intestinalis* (as *Enteromorpha intestinalis*).

Evidence on salinity tolerances was also found for the associated species that occur in low numbers in this biotope. Like other intertidal species these are exposed to changes in salinity resulting from evaporation or run-off and consequently can tolerate changes in salinity. Populations of *Patella vulgata* extend into the mouths of estuaries surviving in salinities down to about 20psu. However, growth and reproduction may be impaired in reduced salinity. Little *et al*. (1991), for example, observed reduced levels of activity in limpets after heavy rainfall and in the laboratory activity completely stopped at 12psu although individuals died only when the salinity was reduced to 3-1psu (Fretter & Graham, 1994). In experiments where freshwater was trickled over the shell Arnold (1957) observed limpets withdrawing and clamping the shell onto the substratum. There appears to be an increasing tolerance of low salinities from the lower to the upper limit of distribution of the species on the shore (Fretter & Graham, 1994) suggesting local acclimation. *Littorina littorea* is found in waters of full, variable and reduced salinities (Connor *et al*., 2004) and so populations are not likely to be highly intolerant of decreases in salinity. Therefore, it appears that the biotope would have low intolerance to a decrease in salinity. On return to normal conditions recovery is likely to be very rapid.

Sensitivity assessment. The characterizing *Ulva* species and the associated species *Littorina littorea* are considered able to tolerate a change from full to variable or variable to reduced salinity. However, based on reported distributions and the results of experiments to assess salinity tolerance thresholds and behavioural and physiological responses in *Patella vulgata* it is considered that these species would tolerate a change in salinity from full to variable but that a change from variable to reduced salinity may reduce habitat suitability. As these species occur only in low numbers and do not characterize the biotope the sensitivity assessment is based on the *Ulva* species alone. Biotope resistance is therefore assessed as 'High' and resilience as 'High', based on no effect to recover from and the biotope is considered to be 'Not sensitive'.

Water flow (tidal current) changes (local)	Medium Q: High A: Low C: High	High Q: High A: High C: High	Low Q: High A: Low C: High

The key characterizing species of this biotope, *Ulva intestinalis* and *Ulva lactuca* are flexible and conform to the direction of the flow reducing drag and breakage. However, experimental studies show that exposure to currents results in sloughing of tissue and higher current velocities result in breakage of the thallus.

Kennison & Fong (2013) found that *Ulva intestinalis*, settled on ceramic tiles and deployed in the field were subject to greater losses at mean flow speeds of 0.2 m/s (approximately 16% of biomass) than the 8% loss from individuals subject to lower flows (0.15 m/s). These results agree with those from another study by Flindt *et al.* (2007) that subjected *Ulva* spp. to increased water flows in flume tanks. They distinguished *Ulva* sp. and *Enteromorpha* sp. in their sloughing experiments but not to species level. Water flow rates were increased from still incrementally by 0.005 m/s and the amount of biomass sloughed off was measured. At a current speed of 0.12 m/s, 3-4% of biomass of *Ulva* sp. was removed, increasing to 4-7% at 0.15 m/s and 40-50% at 0.4 m/s. *Enteromorpha* sp. were slightly more resistant; at current flows of 0.2 m/s 1% of biomass was sloughed, increasing to 20% at 0.35 m/s. Flindt *et al.*, (2007) estimated from regression models that the current speeds at which all *Ulva* spp., would be totally removed were 0.82 m/s and 1.28 m/s for *Enteromorpha* sp. Note, *Enteromorpha* is now a synonym of *Ulva*. The authors assume that the *Enteromorpha* sp. mentioned in their study relate to the more filamentous and tube-like growth form of *Ulva intestinalis*.

Modelled predictions of thallus breakage based on laboratory studies of *Ulva lactuca* on bivalve shells estimate that large *Ulva lactuca* (>50 cm in length) are unlikely to persist where currents exceed 0.5 m/s, whereas smaller individuals (24 cm in length) are unlikely to be present where current speeds exceed 1 m/s (Hawes & Smith, 1995). Increased water flows may also be beneficial where these enhance recruitment. Increased water velocities can enhance recruitment through increased larval supply (Kennison & Fong, 2013). Houghton *et al.* (1973) observed that swarmers of *Ulva* were able to settle onto surfaces subjected to water speeds of up to 10.7 knots, suggesting that changes may not inhibit settlement.

Sensitivity assessment. Increased water flow rates may detach and remove biomass of the *Ulva* spp, that characterize this biotope. Experiments suggest that the pressure benchmark is biologically relevant, i.e. increases at the pressure benchmark could result in loss and detachment. However as this biotope occurs in the upper eulittoral or littoral fringe in rockpools (Connor *et al.*, 2004) it will only be exposed for very limited periods and rapid growth of *Ulva* sp. may mitigate the loss of tissue during the growing season. The experiments do not detail the amount of time that individuals were exposed to flows so that extrapolating the results to predicted losses, particularly for breakage is problematic. Based on the breakage studies (Hawes & Smith, 1995), resistance of *Ulva* sp., to an increase in water flow at the pressure benchmark is assessed as ‘Medium’ as smaller individuals can persist at flow rates that are almost double those of larger plants and duration of exposure is limited. Resilience is assessed as ‘High’ and sensitivity is assessed as ‘Low’.

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

As *Ulva intestinalis* is able to tolerate dessication stress it is often very abundant on the high shore where desiccation stress is the primary factor controlling seaweed distribution, and may even be found above the tidal limits of the shore. *Ulva intestinalis* (studied as *Enteromorpha intestinalis*) can survive several weeks of living in completely dried out rock pools, while becoming completely bleached on the uppermost layers, but remaining moist underneath the bleached fronds. However, dessication stress of germlimgs may be lower than adults Hruby & Norton (1979) found that 7-14 day old germlings of *Ulva* (studied as *Enteromorpha*) were more tolerant of desiccation than earlier stages, so an increase in desiccation stress, resulting in the rock pool drying out may impact more adversely on newly settled germlings than more mature plants

Increased emergence may reduce habitat suitability for the associated species, although the mobile species present within the biotope, *Patella vulgata* and the littorinids are able to relocate to preferred shore levels. An increase in emergence may result in migration downshore, while decreased emergence may increase habitat suitability of upper littoral fringe biotopes for these species. Grazing by littornids and other species can have a significant structuring impact on biotopes dominated by ephemeral algae (Robles 1982, Albrecht, 1998). An increase in grazers and grazing within this biotope may removal large amounts of algal biomass preventing blooms.

Sensitivity assessment. As this biotope occurs right at the very top of the shore, a change at the pressure benchmark may result in drying of the pool, an increase in environmental stress through increased exposure to air temperatures, increased or decreased salinity and the risk of the pool drying out. Increased submergence would reduce the effects of environmental stress and as this is a key factor maintaining the biotope this may result in a reduction in suitability, depending on the duration of submergence. Increased grazing by littorinids and other grazers facilitated by increased immersion and salinity would also be likely to reduce the biomass of *Ulva* spp. in this instance. Resistance is assessed as ‘Low’ to both an increase and decrease in emergence and resilience as ‘High’ (following habitat recovery). Sensitivity is therefore assessed as ‘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 effects of wave exposure upon rockpool communities high on the shore are likely to depend on tidal amplitude as within a shore, and where the tidal amplitude is significant, the time for which organisms are subjected to wave action will vary along the intertidal gradient. For instance, during neap tide periods, high shore rockpools may remain isolated from the main body of the sea for several days or weeks in concession. During such times wave action is unlikely to be of direct influence other than generating a spray, whilst during periods of tidal immersion wave action may directly affect the community. No direct evidence was found to assess the sensitivity of this biotope to changes in wave exposure at the pressure benchmark. This biotope is recorded from locations that are judged to range from very exposed, exposed, moderately exposed and sheltered (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 three wave exposure categories, 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.

Sensitivity assessment. The natural wave exposure range of this biotope is considered to exceed changes at the pressure benchmark and this biotope is considered to have 'High' resistance and 'High' resilience (by default), to this pressure (at the benchmark).

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.

Contamination by non-synthetic chemicals, at levels greater than the pressure benchmark may adversely impact the biotope. The order of metal toxicity to algae varies, with the algal species and experimental conditions, but generally the order is Hg>Cu>Cd>Ag>Pb>Zn (Rice *et al*., 1973; Rai *et al*., 1981). The effects of copper on macrophytes have been more extensively studied than the effects of any other metal owing to its use in antifouling paints. Lewis *et al*. (1998) investigated the influence of copper exposure and heatshock on the physiology and cellular stress response of *Ulva intestinalis* (as *Enteromorpha intestinalis*). Heat shock proteins (HSPs) are known to be expressed in response to a variety of stress conditions, including heavy metals (Lewis *et al*., 1999). *Ulva intestinalis* was exposed to a range of copper concentrations (0-500 µg -1 for 5 days, to assess the effect of copper exposure on stress proteins (Stress-70 levels) and physiology of the seaweed. Stress-70 was induced by copper exposure, but was found to be no better an indicator of copper exposure than measurement of growth, which is inhibited by copper.

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

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

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

Hydrocarbon contamination, at levels greater than the benchmark, e.g. from spills of fresh crude oil or petroleum products, may cause significant loss of *Ulva* spp. Likely effects include smothering, inhibition of respiration and photosynthesis, bleaching and interference with reproduction, so that affected populations may be destroyed. However, the species tends to recover very rapidly from oil pollution incidents. For instance, after the Torrey Canyon tanker oil in 1967, grazing species were killed, and a dense flush of ephemeral green algae (*Ulva*, *Blidingia*) appeared on the rocky shore within a few weeks and persisted for up to one year (Smith, 1968).

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

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

Contamination at levels greater than the benchmark may impact this biotope. Some evidence for adverse effects of chemical pollution on the key characterizing species, *Ulva intestinalis*, has been found. Although herbicides tend not to be used directly in the marine environment, they can enter estuarine areas via river discharge and runoff. Paraquat and 3AT were tested for their effects on the settlement, germination and growth of *Ulva* (as *Enteromorpha*) (Moss & Woodhead, 1975). They found that zygotes were able to develop into filaments in the presence of Paraquat at 7 mg/L, but that germination was deferred at higher concentrations. Zygotes demonstrated increased resistance when they settled in clumps on the substratum, and green thalli of *Ulva* were more susceptible than ungerminated zygotes. *Ulva* was more intolerant of 3AT than to Paraquat (Moss & Woodhead, 1975).

Synthetic chemicals used as antifouling agents may be directly introduced into the marine environment. Scarlett *et al*. (1997) analyzed water samples taken from the Plymouth Sound locality for the presence of the s-triazine herbicide, Irgarol 1051, which is an ingredient of antifouling paints used on pleasure boats and ships. Irgarol 1051 was detected at all sampling sites within the Sound; the highest levels were found in close proximity to areas of high boat density, especially where water flow was restricted within marinas, although concentrations within the semi-enclosed Sutton Harbour were less than values predicted from leach rate data. The highest detected concentration of over 120 ng/L significantly inhibited the growth of *Ulva intestinalis* (as *Enteromorpha intestinalis*) spores under laboratory conditions; the no effect concentration was 22 ng/L. Photosynthetic efficiency in the adult frond of *Ulva intestinalis* from Sutton Harbour marina was inhibited by Irgarol 1051 in the laboratory with an EC 50 (72 h) of 2.5 µg/L. A small adverse impact on *Ulva intestinalis* reproduction within harbours is therefore likely.

Following the Torrey Canyon tanker oil spill, copious amounts of solvent based detergents were sprayed directly on to the shore. Algae on the higher shore was especially affected, and included *Ulva intestinalis* (as *Enteromorpha intestinalis)* in high level rock pools where it was killed (Smith, 1968).Synthetic compound contamination, at levels greater than the benchmark, is likely to have a variety of effects depending the specific nature of the contaminant and the species group(s) affected. Hoare & Hiscock (1974) reported that the limpet *Patella vulgata* was excluded from sites within 100-150m of the discharge of acidified, halogenated effluent in Amlwch Bay. Limpets are also extremely intolerant of aromatic solvent based dispersants used in oil spill clean-up. During the clean-up response to the *Torrey Canyon* oil spill nearly all the limpets were killed in areas close to dispersant spraying. Viscous oil will not be readily drawn in under the edge of the shell by ciliary currents in the mantle cavity, whereas detergent, alone or diluted in seawater, would creep in much more readily and be liable to kill the limpet (Smith, 1968). A concentration of 5ppm killed half the limpets tested in 24 hours (Southward & Southward, 1978; Hawkins & Southward, 1992). Acidified seawater affects the motility of *Patella vulgata*. At a pH of 5.5 motility was reduced whilst submerged but individuals recovered when returned to normal seawater. At a pH of 2.5 total inhibition of movement occurred and when returned to normal seawater half had died (Bonner *et al*., 1993). Reduced motility reduces time for foraging and may result in decreased survival of individuals. Acidified seawater can also change the shell composition which will lead to a decrease in its protective nature and hence survival (Bonner *et al*., 1993). Short periods (48 hours) are unlikely to have much effect on a population but long periods (1 year) may cause reduced grazing and an increase in algal growth. However, seawater is unlikely to reach pH 2.5 therefore intolerance to slight changes in pH will be low. Gastropod molluscs are known to be intolerant of endocrine disruption from synthetic chemicals such as tri-butyl tin (Cole *et al*., 1999). However no information on the specific effects of tri-butyl tin on *Patella vulgata* was found. Hoare & Hiscock (1974) reported that in Amlwch Bay *Patella vulgata* was excluded from sites within 100-150 m of the discharge of acidified, halogenated effluent.

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

The key characterizing *Ulva* spp. are known to be able to acquire large concentrations of substances from surrounding water. In the vicinity of the Sellafield nuclear plant, England, *Ulva* (as *Enteromorpha*) sp. accumulated zirconium, niobium, cerium and plutonium-239, however the species appeared to be unaffected by the radionuclides (Clark, 1997). Based on this evidence, the resistance of the biotope to this pressure at the benchmark, is assessed as 'High', resilience is assessed as 'High' (by default), and the biotope is assessed as 'Not sensitive'.

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	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

Algae produce oxygen by photosynthesis, and this may raise oxygen concentrations in rock pools up to three times the saturation value. At night, when photosynthesis has ceased, algal respiration may utilize much of the available oxygen and minimum values of 1-5 % saturation have been recorded (Morris & Taylor, 1983). Algae in this biotope are therefore unlikely to be adversely affected by decreased oxygen as they re-oxygenate the rock pool. The evidence for anoxia tolerances have, however been reviewed.

Where nutrients and other factors support rapid growth, large blooms of *Cladophora* spp. and *Ulva* spp. can occur, as these die and decay, they can create anoxic conditions in the water column and the sediments they overlay. Some tolerance for anoxia may therefore be expected that allows a proportion of the population to survive and reproduce during and after these conditions. Vermaat & Sand-Jensen (1987) tested the survival of discs of *Ulva lactuca* during prolonged exposure to anoxia. The 113 mm^2 discs were taken from wild plants collected in the Roskilde Fjord, Denmark in late autumn. Anoxic conditions were created in the laboratory by bubbling with N_2 gas. Exposure to anoxia for two months did not affect survival but did result in increased respiration and a decrease in growth. Corradi *et al*., (2006) used similar sized thallus discs from *Ulva* spp. (113 mm^2), collected from the lagoon Sacca di Goro (Po River Delta) during spring to test the effects of hypoxia on gamete production for *Ulva* sp. The test oxygen concentrations ranged from 1.78 – 4.02 µmol /L (the benchmark of 2mg/l refers to 64 µmol/L). The exposure to hypoxia was not lethal to the discs and following resumption of normal oxygen conditions gametes were produced.

The associated species also show high tolerances for reduced oxygen. The effect of severe hypoxia on the copepod *Tigriopus brevicornis* is for it to enter a quiescent/dormant state during which its metabolic rate is significantly reduced. It recovers on return to optimal conditions (McAllen *et al*., 1999). *Littorina littorea* also have a high tolerance for low oxygen conditions and can easily survive 3-6 days of anoxia (Storey *et al*., 2013). In laboratory experiments a reduction in the oxygen tension of seawater from 148mm Hg (air saturated seawater) to 50mm Hg rapidly resulted in reduced heart rate in limpets of the genus *Patella* (Marshall & McQuaid, 1993). Heartbeat rate returned to normal in oxygenated water within two hours. Limpets can survive for a short time in anoxic seawater; Grenon & Walker, (1981) found that in oxygen free water limpets could survive up to 36 hours, although Marshall & McQuaid (1989) found a lower tolerance for *Patella granularis*, which survived up to 11 hours in anoxic water. It should be noted that the mobile littorinids and *Patella vulgata* would be able to leave a deoxygenated rockpool and can breathe air.

Sensitivity assessment. No direct evidence for the effects of hypoxia on whole plants in-situ was available. However the results of the laboratory experiments which tested parts of *Ulva* individuals to either prolonged anoxia or short-term hypoxia at levels that exceed the benchmark, indicate that *Ulva* have 'High' resistance to this pressure and 'High' resilience by default. The associated species, littorinids and *Patella vulgata* are considered to be 'Not Sensitive' to de-oxygenation at the pressure benchmark. The experiments cited as evidence (Grenon & Walker, 1981 and Barnes *et al*.,1963) exceed the duration and/or magnitude of the pressure benchmark. Biotope resistance is therefore assessed as 'High' and resilience as 'High' (no effect to recover from), resulting in a sensitivity of 'Not sensitive'.

Nutrient enrichment	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

This pressure relates to increased levels of nitrogen, phosphorus and silicon in the marine environment compared to background concentrations. The pressure benchmark is set at compliance with Water Framework Directive (WFD) criteria for good status, based on nitrogen concentration (UKTAG, 2014).

The criteria for status under the WFD with regard to nutrient enrichment is concerned with the presence or absence of 'blooms' of opportunistic algae , including the key characterizing *Cladophora* spp. and *Ulva* spp. found in this biotope, that act as indicators of enrichment (eutrophication). The abundance and biomass of these species are used in the implementation of the WFD as indicators to assess the condition of waterbodies. The criteria for achieving good status states that there should be: 'limited cover (<15%) and low biomass (<500g/m^2) of opportunistic macroalgal blooms...macroalgae cover shows slight signs of disturbance with a slight deviation from reference conditions' (Wells *et al*., 2014).

The high abundance and biomass of *Ulva* spp, that characterize this biotope would suggest that this biotope would fail to achieve 'good status'. Theoretically, compliance with good status would require a significant loss of characterizing species, suggesting that the biotope would be sensitive to this pressure at the benchmark (i.e. it represents a significant impact on biotope character). However, the biotope is considered to develop in response to chronic stressors in tide pools high on the shore. Typical blooms of opportunistic macroalgae, occur in sheltered areas such as estuaries (Kennison & Fong, 2013) and are likely to form as unattached mats over sediments rather than rocky shores, the character of these is therefore different to the assessed biotope.

Opportunistic algae, including *Ulva* spp. cannot store nutrients in the thallus (unlike larger, long-lived species) and are adapted to efficiently capture and utilise available nutrients in the water column (Pedersen *et al*., 2009). A large body of field observations and experiments, surveys and laboratory experiments confirm that the characterizing *Ulva* spp, can utilise high levels of nutrients for growth (Martínez *et al*., 2012) and that enhanced recruitment (Kraufvelin, 2007) and growth of this genus can occur in enriched areas (Kennison & Fong, 2013, Vaudrey *et al*., 2010). Such as *Ulva* sp. in the Lagoon of Venice (Sfriso *et al*. 1987) and *Cladophora* sp. in Laholm Bay, Sweden(Baden *et al*. 1990). In areas where nutrient availability is lower either naturally or through management to reduce anthropogenic inputs, *Ulva* spp. may be negatively affected through reduced growth rate and species replacement (Martínez *et al*., 2012; Vaudrey *et al*., 2010).

The associated species *Littorina littorea* occurs on all British and Irish coasts, including lower salinity areas such as this estuarine biotope where nutrient loading is likely to be higher than elsewhere. Higher nutrient levels may benefit the algal substrata and food used by the snail. In situations with nutrient enrichment, primary productivity in terms of biofilms and/ or green algae will generally be enhanced, which may supply more food or more nutrient rich food. This can reduce the browsing distances and periods of *Littorina*, reducing times spent searching for food (Diaz *et al*. 2012). After five months of nutrient addition in experimental mesocosms, *Littorina* abundance and biomass had increased compared to controls. Enriched mesocosms experiments were treated with 32 lM inorganic nitrogen (N) and 2 lM inorganic phosphorus (P) above the background levels in the Oslofjord continuously in the period April–September 2008. These nutrient addition levels are similar to concentrations recorded in eutrophic areas locally (Kristiansen & Paasche, 1982; cited in Diaz *et al*. 2012) and globally (Cloern, 2001; cited in Diaz *et al*. 2012).

Sensitivity assessment. If nutrient levels were to increase (exceeding the pressure benchmark) enhanced growth of *Cladophora* spp. and *Ulva* spp. would be expected in response and this is not considered to significantly alter the character of the biotope. *Cladophora* and *Ulva* spp. may decline in response to reductions in nutrient levels, in habitats where other species more typical of undisturbed species are able to recolonize. However, as this biotope is structured by salinity variations and other environmental stressors rather than nutrient enrichment, other species are not considered to establish following decreases in nutrient levels and *Cladophora* and *Ulva* spp, would be likely to remain the dominant species. The biotope is therefore considered to have 'High' resistance to this pressure and 'High' resilience, (by default) and 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

Organic enrichment may lead to eutrophication with adverse environmental effects including deoxygenation, algal blooms and changes in community structure (see nutrient enrichment and de-oxygenation). Little evidence was found to support this assessment, Cabral-Oliveira *et al*., (2014), found higher abundances of juvenile *Patella* sp. and lower abundances of adults closer to sewage inputs, Cabral-Oliveira *et al*., (2014) suggested the structure of these populations was due to increased competition closer to the sewage outfalls.

Sensitivity assessment. No empirical evidence was found to support an assessment for the key characterizing *Ulva* spp., or the associated species that are present within this biotope. As organic matter particles in suspension or re-suspended could potentially be utilised as a food resource by filter feeders with excess likely to be rapidly removed by wave action, overall resistance of the biological assemblage within the biotope is considered to be 'High' and resilience was assessed as 'High', so that this biotope is judged to be 'Not sensitive'.

Physical Pressures

	Resistance	Resilience	Sensitivity
Physical loss (to land or freshwater habitat)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

All marine habitats and benthic species are considered to have a resistance of 'None' to this pressure and to be unable to recover from a permanent loss of habitat (resilience is 'Very Low').

Sensitivity within the direct spatial footprint of this pressure is therefore ‘High’. Although no specific evidence is described confidence in this assessment is ‘High’, due to the incontrovertible nature of this pressure.

Physical change (to another seabed type)	None Q: Low A: NR C: NR	Very Low Q: Low A: NR C: NR	High Q: Low A: Low C: Low

This biotope occurs in tidepools on hard substrata where the key characterizing *Ulva and Cladophora* spp. can attach to the rock. A soft sedimentary habitat would not retain water and would be unsuitable for these species and the associated species *Patella vulgata* (although littorinids occur on sediment). A change to a soft sedimentary biotope would lead to the development of a biological assemblage more typical of the changed conditions.

Sensitivity assessment. A change to a sedimentary habitat would remove this biotope, resistance is assessed as ‘None’ and resilience as ‘Very Low’ as the change is considered to be permanent. Sensitivity is therefore assessed 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

Not relevant to this biotope which occurs in tidepools on bedrock (Connor *et al*., 2004).

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 key characterizing *Ulva* and *Cladophora* spp. and associated species are epifauna or epiflora occurring on rock in tidepools 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: Medium C: Medium	High Q: High A: High C: High	Low Q: High A: Medium C: Medium

No direct evidence was found to assess how the key, characterizing, *Cladophora* and *Ulva* spp. respond to surface abrasion. *Ulva* spp. fronds are very thin and could be torn and damaged and individuals may be removed from the substratum, altering the biotope through changes in abundance and biomass. *Ulva* spp. cannot repair damage or reattach but torn fronds could still photosynthesise and produce gametes. Tearing and cutting of the fronds has been shown to stimulate gamete production and damaged plants would still be able to grow and reproduce. *Ulva* spp. can also form unattached mats (particularly in response to nutrient enrichment): damage and removal may, therefore, not lead to mortality of impacted individuals. *Cladophora* spp. have a relatively tough thallus (Dodds & Gudder, 1992) but no direct evidence was found for resistance to abrasion. In Kimmeridge Bay in Southern England, Pinn & Rodgers (2005) found that the abundance of *Cladophora rupestris* was lower at a more heavily visited and trampled site.

The limpets and littorinids that occur in low densities in this biotope, have some protection from hard shells but abrasion may damage and kill individuals or detach them from suitable habitats. All removed barnacles would be expected to die as there is no mechanism for these to reattach. Removal of limpets may result in these being displaced to a less favourable habitat and injuries to foot muscles in limpets may prevent reattachment. Although limpets and littorinids may be able to repair shell damage, broken shells while healing will expose the individual to more risk of desiccation and predation. Evidence for the effects of abrasion are provided by a number of experimental studies on trampling (a source of abrasion) and on abrasion by wave thrown rocks and pebbles.

Povey & Keough (1991) in experiments on shores in Mornington peninsula, Victora, Australia, found that limpets may be relatively more resistant to abrasion from trampling. Following step and kicking experiments, few individuals of the limpet C*ellana trasomerica*, (similar size to *Patella vulgata*) suffered damage or relocated (Povey & Keough, 1991). One kicked limpet (out of 80) was broken and 2 (out of 80) limpets that were stepped on could not be relocated the following day (Povey & Keough, 1991). On the same shore less than 5% of littorinids were crushed in single step experiments (Povey & Keough, 1991).

Shanks & Wright (1986), found that even small pebbles (<6 cm) that were thrown by wave action in Southern California shores could smash owl limpets (*Lottia gigantea*). Average, estimated survivorship of limpets at a wave exposed site, with many loose cobbles and pebbles allowing greater levels of abrasion was 40% lower than at a sheltered site. Severe storms were observed to lead to almost total destruction of local populations of limpets through abrasion by large rocks and boulders. In sites with mobile cobbles and boulders increased scour results in lower densities of *Littorina* spp. compared with other, local sites with stable substratum (Carlson *et al*., 2006).

Sensitivity assessment. The impact of surface abrasion will depend on the footprint, duration and magnitude of the pressure. In response to a single event of abrasion a proportion of the *Cladophora* spp. and *Ulva* population may be removed, but damaged individuals, *in-situ* would be capable of growth and reproduction. Based on additional evidence for the associated species from the step experiments and the relative robustness of the associated species, the resistance of the biotope, to a single abrasion event is assessed as 'Medium' and recovery as 'High', so that sensitivity is assessed as 'Low'. Resistance will be lower (and hence sensitivity greater) to abrasion events that exert a greater crushing force than the trampling examples the assessment is based on).

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

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

Changes in suspended solids (water clarity)	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Intertidal biotopes will only be exposed to this pressure when submerged during the tidal cycle and thus have limited exposure. Siltation, which may be associated with increased suspended solids is assessed separately. As a photoautotroph, the key characterizing *Ulva* spp., are likely to benefit from reduced turbidity, as the light attenuating effects of turbid water reduce photosynthesis. However experiments have shown that *Ulva* is a shade tolerant species and can compensate for reduced irradiance by increasing chlorophyll concentration and light absorption at low light levels. *Ulva* spp. were able to survive over two months in darkness and to begin photosynthesising immediately when returned to the light (Vermaat & Sand-Jensen, 1987). Limited shading from suspended sediments is therefore not considered to negatively affect this genus. Suspended sediments may however have abrading effects on the fronds of *Ulva* spp. Tolhurst *et al*. (2007) found that *Ulva intestinalis* germlings kept in tanks and exposed to 100 mg/l of suspended sediment showed reduced growth. Similarly, Hyslop & Davies (1998) found that *Ulva lactuca* lost weight when kept in flasks with 1 g/l of colliery waste that was shaken for 1 hour every day for 8 days. The experimental solids level, however, exceeds the pressure benchmark and oscillatory flows will be limited to periods where he rockpool is inundated by the tide and exposed to waves. It should be noted that both *Cladophora* spp. and *Ulva* spp. can occur in estuaries and/or eutrophicated areas where levels of suspended solids can be very high.

Sensitivity assessment. The exposure of this upper shore biotope to suspended sediments in the water column will be limited to the short immersion periods, however silts deposited during emersion may remain on the fronds inhibiting photosynthesis in sheltered areas. The biotope is considered to be ‘Not sensitive’ to a reduction in suspended solids. An increase in suspended solids from clear (<10 mg/l) to intermediate (10-100 mg/l) may lead to some sub-lethal abrasion of fronds and reduction in photosynthesis but this will be compensated by the high growth rates exhibited by *Cladophora* and *Ulva* spp. Resistance is therefore assessed as ‘High’ and resilience as ‘High’ (by default) so that the biotope is considered to be ‘Not sensitive’.

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

Observations and experiments indicate that *Ulva* spp. have relatively high tolerances for the stresses induced by burial (darkness, hypoxia and exposure to sulphides). Vermaat & Sand-Jensen , (1987) exposed thallus discs (113 mm^2) of *Ulva lactuca* to darkness and anoxia and sulphides at winter temperatures. It was found that these conditions did not affect survival over two months, although exposure to anoxia increased respiration and reduced growth (Vermaat & Sand-Jensen, 1987). These experiments were undertaken using *Ulva lactuca* collected from Roskilde Fjord, Denmark. Corradi *et al*., (2006) subjected *Ulva* sp. collected from the Sacca di Goro, Italy to similar stressors (hypoxia 1.78 – 4.02 µmol /L, or sulphide at 1mM, both treatments in darkness) for 3,5 or 7days at 20°C. The thallus discs survived but no gametes were produced until recovery in oxygenated conditions. The high tolerance of darkness, anoxia and hydrogen sulphides allows buried fragments of *Ulva* sp. to overwinter, protected from frosts. Kamermans *et al*., (1998) found that parts of *Ulva* thalli that were collected from the Veerse Meer lagoon in the Netherlands could resume growth in the spring when returned to the surface. *Ulva* spp. in sheltered areas are often unattached to the substratum and therefore are not considered a direct proxy for attached *Ulva* spp. in this biotope.

Although *Ulva* spp. present in sedimentary habitats may be able to survive the chemical stress of burial and re-grow from surviving fragments, evidence for attached individuals from rocky shores suggest that resistance to this pressure may be lower. *Ulva lactuca* is a dominant species on sand-affected rocky shores in New Hampshire (Daly & Mathieson, 1977) although Littler *et al*., (1983) suggest that *Ulva* sp., are present in areas periodically subject to sand deposition not because they are able to withstand burial but because they are able to rapidly colonise sand-scoured areas (such as this biotope). *Ulva* spp. have, however, been reported to form turfs that trap sediments (Airoldi, 2003, references therein) suggesting that resistance to chronic rather than acute siltation events may be higher. In general, propagules, early post-settlement stages and juveniles suffer severe stress and mortality from sediments (Airoldi, 2003). Hyslop *et al*. (1997) compared the composition, abundance and distribution of dominant plants and animals at several rocky shores affected or unaffected by dumping of colliery wastes along the coastline of northeast England. They reported that while the distribution of animals was not related to colliery wastes, diversity of macroalgae was significantly negatively correlated with colliery waste inputs and particularly dramatic reductions in cover at the affected sites were observed for *Ulva lactuca*. The authors suggested that, because colliery waste leaches much of its toxic chemical content into the sea, detrimental effects were most likely related to the physical presence of sediments.

The associated species, *Patella vulgata* and *Littorina* spp. are likely to be negatively affected by siltation. Experiments have shown that the addition of even thin layers of sediment (approximately 4 mm) inhibit grazing and result in loss of attachment and death after a few days Airoldi & Hawkins (2007). The laboratory experiments are supported by observations on exposed and sheltered shores with patches of sediment around Plymouth in the south west of England as *Patella vulgata* abundances were higher where deposits were absent (Airoldi & Hawkins (2007). Littler *et al*., (1983) found that the another limpet species, *Lottia gigantea* on southern Californian shores was restricted to refuges from sand burial on shores subject to periodic inundation by sands. Chandrasekara & Frid (1998) specifically tested the siltation tolerance of *Littorina littorea*. Burial to 5cm caused mortality within 24 hours at simulated summer and winter temperatures if the snails could not crawl out of the sediment (Chandrasekara & Frid, 1998). If the sediment is well oxygenated and fluid (as with high water, high silt content) a few snails (1-6 out of 15 in the experiment, depending on temperature, sediment and water content) may be able to move back up through 5 cm of sediment (Chandrasekara & Frid, 1998). Approximately half of the test individuals could not regain the surface from 1cm of burial except in the most favourable conditions (low temperatures, high water, high silt when a majority (10 out of 15) of the test cohort surfaced. Field observations support the findings that *Littorina littorea* are generally unable to survive smothering. Albrecht & Reise (1994) observed a population of *Littorina littorea* in a sandy bay near the Sylt island in the North Sea. They found that the accretion of mud within *Fucus* strands and subsequent covering of *Littorina* by the sediment resulted in them suffocating and a significant reduction in their abundance.

Sensitivity assessment. A covering of sediment to a depth of 5 cm is likely to partially cover erect *Cladophora* spp. and may fully cover the flexible *Ulva* spp. Unless the sediment is removed by the incoming tide (which may be some time on the high shore where pools may be isolated from the main body of the sea for several days in succession), photosynthesis would be inhibited and fronds of macroalgae may begin to decay. If shallow the pool itself may be infilled. The available evidence indicates that *Ulva* spp. can survive some of the stressors associated with burial but would be sensitive to abrasion and scouring forces resulting from the deposition and removal of sediments. Spores, germlings and juveniles are likely to be highly intolerant of smothering by sediment (Vadas *et al*. 1992).. Even small deposits of sediments are likely to result in local removal of limpets and littorinids and these are considered to have ‘Low’ resistance to this pressure based primarily on observations and experiments of Airoldi & Hawkins, (2007). The sensitivity assessment for the biotope is based on *Ulva* and *Cladophora* spp. Within pools siltation by 5 cm of fine sediments is considered likely to remove a proportion of the population through scour effects and resistance is assessed as ‘Low-Medium’, recovery is assessed as ‘High’ (following removal of silts) and sensitivity is assessed as ‘Low’.

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

Observations and experiments indicate that *Ulva* spp. have relatively high tolerances for the stresses induced by burial (darkness, hypoxia and exposure to sulphides). Vermaat & Sand-Jensen (1987) exposed thallus discs (113 mm^2) of *Ulva lactuca* to darkness and anoxia and sulphides at winter temperatures. It was found that these conditions did not affect survival over two months, although exposure to anoxia increased respiration and reduced growth (Vermaat & Sand-Jensen, 1987). These experiments were undertaken using *Ulva lactuca* collected from Roskilde Fjord, Denmark. Corradi *et al*., (2006) subjected *Ulva* sp. collected from the Sacca di Goro, Italy to similar stressors (hypoxia 1.78 – 4.02 μmol /L, or sulphide at 1mM, both treatments in darkness) for 3, 5 or 7days at 20°C. The thallus discs survived but no gametes were produced until recovery in oxygenated conditions. The high tolerance of darkness, anoxia and hydrogen sulphides allows buried fragments of *Ulva* sp. to overwinter, protected from frosts. Kamermans *et al*., (1998) found that parts of *Ulva* thalli that were collected from the Veerse Meer lagoon in the Netherlands could resume growth in the spring when returned to the surface. *Ulva* spp. in sheltered areas are often unattached to the substratum and therefore are not considered a direct proxy for attached *Ulva* spp. in this biotope.

Although *Ulva* spp. present in sedimentary habitats may be able to survive the chemical stress of burial and re-grow from surviving fragments, evidence for attached individuals from rocky shores suggest that resistance to this pressure may be lower. *Ulva lactuca* is a dominant species on sand-affected rocky shores in New Hampshire (Daly & Mathieson, 1977), although Littler *et al*., (1983) suggest that *Ulva* sp., are present in areas periodically subject to sand deposition not because they are able to withstand burial but because they are able to rapidly colonise sand-scoured areas (such as this biotope). *Ulva* spp. have, however, been reported to form turfs that trap sediments (Airoldi, 2003, references therein) suggesting that resistance to low-level chronic rather than acute siltation events may be higher. In general, propagules, early post-settlement stages and juveniles suffer severe stress and mortality from sediments (Airoldi, 2003). Hyslop *et al*. (1997) compared the composition, abundance and distribution of dominant plants and animals at several rocky shores affected or unaffected by dumping of colliery wastes along the coastline of northeast England. They reported that while the distribution of animals was not related to colliery wastes, diversity of macroalgae was significantly negatively correlated with colliery waste inputs and particularly dramatic reductions in cover at the affected sites were observed for *Ulva lactuca*. The authors suggested that, because colliery waste leaches much of its toxic chemical content into the sea, detrimental effects were most likely related to the physical presence of sediments.

The associated species are likely to be negatively affected by siltation as outlined above for the ‘Light’ siltation pressure and no or very few, impacted individuals would be predicted to survive.

Sensitivity assessment. The available evidence indicates that *Ulva* spp. can survive some of the stressors associated with burial but would be sensitive to abrasion and scouring forces resulting from the deposition and removal of sediments. Even small deposits of sediments are likely to result in local removal of limpets and limpets are considered to have ‘No’ resistance to this pressure based primarily on observations and experiments of Airoldi & Hawkins, (2007) and Chandrasekara & Frid, 1998). The sensitivity assessment for the biotope is based on *Ulva* spp. Siltation by 30 cm of fine sediments is considered to remove a proportion of the population through scour effects and resistance is assessed as ‘Low’, recovery is assessed as ‘High’ (following removal of silts) and sensitivity is assessed as ‘Low’.

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	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

No evidence.

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.

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

A number of experiments have demonstrated that the key characterizing species *Ulva lactuca*, has high tolerance for shading and can survive periods of darkness. Vermaat & Sand-Jensen (1987) found that *Ulva lactuca*, collected from Roskilde Fjord in Denmark in late autumn had extremely high shade tolerances. Increasing chlorophyll concentration and light absorption allowed the individuals (studied experimentally as thallus discs of 113 mm^2) to continue to grow at the lowest irradiance tested (0.6 µE m^2/s). This corresponds to the lowest light-levels of deep-living marine macroalgae and phytoplankton growing under ice (Vermaat & Sand-Jensen, 1987). *Ulva lactuca* was able to survive two months in darkness and was able to resume growth immediately when transferred to the light (Vermaat & Sand-Jensen, 1987).

No direct evidence to assess this pressure was found for the key characterizing species *Patella vulgata* and the littorinids. As both species occur on open rock and in crevices and *under Fucus canopies* they are considered tolerant of a range of light conditions.

Sensitivity assessment. The key *Ulva* spp. that characterizes the biotope are considered to have 'High' resistance to changes in light level, although extreme changes such as complete darkness would prevent photosynthesis and growth and high light levels may be damaging. Recovery is assessed as 'High' by default and the biotope is judged to be 'Not sensitive '.

Barrier to species movement	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

No direct evidence was found to assess this pressure. The key characterizing *Ulva* and *Cladophora* spp. produce large amounts of motile swarmers, throughout the growing season (Niesenbaum, 1988) . The level of supply of potential recruits is considered to be so great that barriers and changes in tidal excursion will not negatively impact populations. The associated species *Patella vulgata* and *Littorina littorea* also produce planktonic larvae that are transported by water movements.. Barriers that reduce the degree of tidal excursion may alter larval supply to suitable habitats from source populations. Conversely the presence of barriers may enhance local population supply by preventing the loss of larvae from enclosed habitats. *Littorina saxatilis* have either limited dispersal or produce crawl away juveniles rather than pelagic larvae (direct development). Barriers and changes in tidal excursion are not considered relevant to these species as dispersal is limited. As the key characterizing species are widely distributed and have larvae capable of long distance transport, resistance to this pressure is assessed as 'High' and resilience as 'High' by default. This biotope is therefore considered to be 'Not sensitive'.

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

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

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.

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

The key characterizing *Cladophora* and *Ulva* spp. may be cultivated for use as biofilters to mitigate pollution, as biomass for biofuel generation or for pharmaceuticals and food. No information was found on current production in the UK and no evidence was found for the effects of gene flow between cultivated species and wild populations. As wild populations are widely distributed and water flow may aid dispersal of swarmers, populations are not considered to be genetically isolated. It is therefore considered that resistance to changes in genetic structure are ‘High’ and that resilience is therefore ‘High’ by default and the biotope is ‘Not sensitive’. The use of genetically modified organisms in the future, which may transfer novel genetic material to wild populations may result in harmful impacts and this assessment would require updating if such scenarios arise.

Introduction or spread of invasive non-indigenous species	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

This biotope occurs where either fresh-water influences or physical disturbances, such as abrasion, prevent the development of a more diverse rocky shore assemblage. Due to the environmental stressors that maintain the biotope the habitat is unsuitable for colonization by most species including invasive, non-indigenous species.

Sensitivity assessment. Based on the high-levels of environmental stress and the lack of habitat overlap and reported impacts with currently recognised invasive, non-indigenous species, this biotope is considered to have ‘High’ resistance and ‘High’ resilience to this pressure and is therefore assessed as ‘Not sensitive’.

Introduction of microbial pathogens	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

No evidence was found that outbreaks of microbial pathogens significantly impact populations of the key characterizing *Cladophora* and *Ulva* spp. Resistance to this pressure is therefore assessed as ‘High’ and recovery as ‘High’ (by default) so that the biotope is considered to be ‘Not sensitive’

Removal of target species	Low Q: Low A: NR C: NR	High Q: High A: High C: High	Low Q: Low A: Low C: Low

The winkle *Littorina littorea* and the limpet *Patella vulgata* occur in low densities in this biotope and may be gathered by hand. However, as these are not key characterizing species the biotope is not considered sensitive to their removal or the reduction in grazing pressure that may result. The key characterizing *Ulva* spp. may be collected from the wild for use in pharmaceuticals and food. Removal of this species in high quantities would alter the character of the biotope, resulting in reclassification. Resistance to harvesting is assessed as ‘Low’ as the genus, is relatively large, attached and accessible and therefore has no escape or other avoidance mechanisms. Resilience is assessed as ‘High’ as cleared areas will be readily colonized. Sensitivity is therefore assessed as ‘Low’.

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

Incidental removal of the characterizing *Ulva* and *Cladophora* spp.would alter the character of the biotope. The ecological services such as primary production provided by these species would also be lost.

Sensitivity assessment. Removal of a large percentage of the characterizing species would alter the character of the biotope, so that it was a bare rock pool. Resistance is therefore assessed as ‘Low’ and recovery as ‘High’ and sensitivity is therefore assessed as 'Low'.

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