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## Marine Information Network

Information on the species and habitats around the coasts and sea of the British Isles

# Mixed furoids, *Chorda filum* and green seaweeds on reduced salinity infralittoral rock

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

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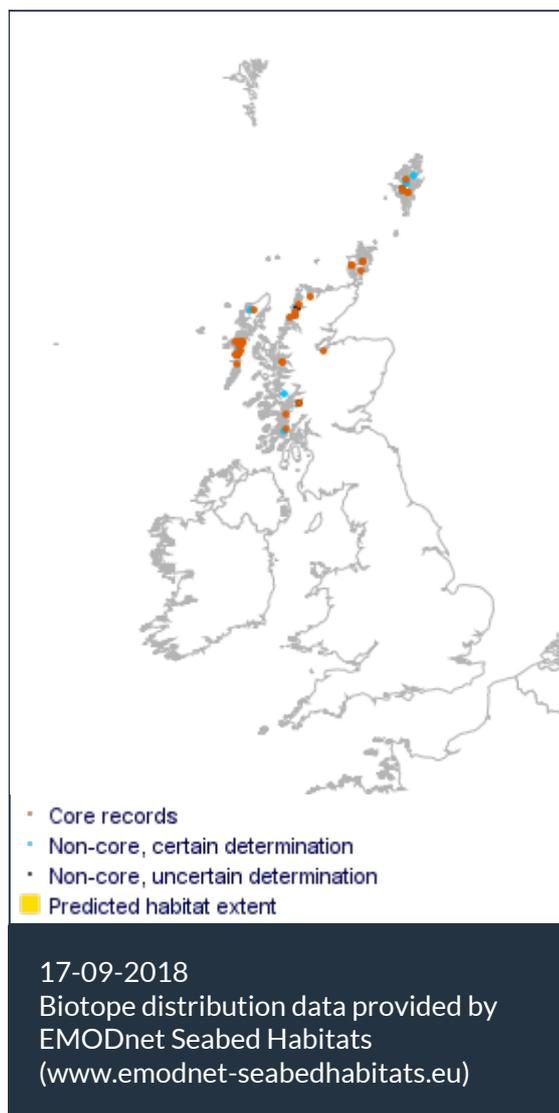


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Fucoids and *Chorda filum* submerged.  
 Photographer: Sue Scott  
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Researched by Frances Perry      Referred by Admin

## Summary

### ☰ UK and Ireland classification

EUNIS 2008	A3.341	Mixed fucoids, <i>Chorda filum</i> and green seaweeds on reduced salinity infralittoral rock
JNCC 2015	IR.LIR.Lag.FChoG	Mixed fucoids, <i>Chorda filum</i> and green seaweeds on reduced salinity infralittoral rock
JNCC 2004	IR.LIR.Lag.FChoG	Mixed fucoids, <i>Chorda filum</i> and green seaweeds on reduced salinity infralittoral rock
1997 Biotope	IR.SIR.Lag.FChoG	Mixed fucoids, <i>Chorda filum</i> and green seaweeds on reduced salinity infralittoral rock

### 🔍 Description

Permanently submerged mixed fucoids on rock in lagoons. *Saccharina latissima* absent, possibly due to the low salinity conditions. The main species are *Fucus vesiculosus* and *Fucus serratus*, with brown

seaweeds *Chorda filum*, *Ascophyllum nodosum*, and Ectocarpaceae can be present as well. Red seaweeds are normally present and include *Mastocarpus stellatus*, *Polyides rotunda*, *Chondrus crispus*, *Ceramium* spp. and coralline crusts. A variety of green seaweeds is also present and include *Ulva* spp., while patches of dense *Cladophora rupestris* may occur on vertical rock faces. The faunal component is restricted to the mussel *Mytilus edulis*, the polychaete *Arenicola marina* and the crab *Carcinus maenas*. Opossum shrimps Mysidae can be present as well. (Information taken from Connor *et al.*, 1997a, b, 2004).

### ↓ Depth range

0-5 m, 5-10 m

### Additional information

Slightly deeper rock often supports *Saccharina latissima* (Slat.Ft), usually surrounded by more extensive areas of sediment. Often, nearby rock supports similar biotopes of submerged fucoids (AscSpAs and FcerUlv) or where salinity is further reduced ProtFur can occur. Seagrass beds thrive well in the muddy sediments of the lagoons and often cover large areas. They include both *Ruppia* spp. and *Zostera marina* and some locations in the Outer Hebrides support dense beds of the nationally rare stonewort *Lamprothamnion papulosum* (Rup and Zmar). The sublittoral mud, which abuts most of the submerged rock, can become anoxic and covered by a bacterial mat of *Beggiatoa* spp. (Beg) (Information from Connor *et al.*, 2004).

### ✓ Listed By

- none -

### Further information sources

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## Habitat review

### 🔄 Ecology

#### Ecological and functional relationships

- The biotope is found in very shallow submerged rocky habitats in lagoons, subject to permanently reduced salinity conditions. These particular habitat conditions lead to a variety of seaweed-dominated communities which include furoids and green filamentous species. The furoids, more typical of intertidal habitats, penetrate into the subtidal under the reduced salinity conditions which are not tolerated by kelps.
- The very sheltered conditions of the biotope enables the development of algal cover on cobbles and pebbles. In these habitats, infaunal organisms such as *Arenicola marina* may also be present.
- The furoid species, and the other macroalgae in the biotope, increase the amount of space available for attachment, they provide shelter from wave action and can be an important food source. High abundances of algae may contribute to the oxygen budget of lagoons.
- *Ectocarpus* sp. is often found growing on other seaweeds.
- Grazing by littorinid snails such as *Littorina littorea* may be important in keeping fast growing ephemeral species such as *Ulva* in check.
- The three-spined stickleback *Gasterosteus aculeatus* is widely distributed throughout north-west Europe and Britain in the intertidal region, particularly in estuaries, and may be present in the SIR.FChoG biotope feeding on a wide range of invertebrates.

#### Seasonal and longer term change

The biotope occurs in extremely sheltered conditions so temporal changes associated with winter storms are not likely. However, seasonal changes in growth and recruitment are often apparent on rocky shores. *Fucus serratus* plants, for example, lose fronds in the winter, followed by regrowth from existing plants in late spring and summer, so that summer cover can be about 250% of the winter level (Hawkins & Hartnoll, 1980). Similar growth patterns may also occur in lagoonal habitats. *Chorda filum* is a summer annual, falling into decay in the autumn and disappearing during winter.

#### Habitat structure and complexity

Furoid biotopes provide a variety of habitats and refugia for other species. The beds of *Fucus serratus* and *Fucus vesiculosus* and the presence of other algae in the biotope increases the structural complexity of the habitat providing a variety of resources that are not available on bare rock. Fronds provide space for attachment of encrusting or sessile epifauna and epiphytic algae and provide shelter from desiccation, heat and predation for invertebrates.

#### Productivity

Macroalgae rocky shore communities are highly productive and can be an important source of food and nutrients. On rocky shores only about 10% of the primary production is directly cropped by herbivores (Raffaelli & Hawkins, 1996) and this is likely to be similar for lagoonal like habitats. Macroalgae, such as *Fucus serratus* and other furoids, exude considerable amounts of dissolved organic carbon which are taken up readily by bacteria and may even be taken up directly by some larger invertebrates. Dissolved organic carbon, algal fragments and microbial film organisms are

continually removed by the sea and can make a contribution to the food of many marine species through the production of planktonic larvae and propagules which contribute to pelagic food chains. However, in lagoonal like habitats such as the SIR.FChoG biotope, where tidal flows and wave exposure are weak these probably enter the food chain of local ecosystems rather than inshore subtidal or offshore ecosystems.

### Recruitment processes

Many rocky shore species, plant and animal, possess a planktonic stage: gamete, spore or larvae which float in the plankton before settling and metamorphosing into adult form. This strategy allows species to rapidly colonize new areas that become available such as in the gaps created by storms. For these organisms it has long been evident that recruitment from the pelagic phase is important in governing the density of populations on the shore (Little & Kitching, 1996). Both the demographic structure of populations and the composition of assemblages may be profoundly affected by variation in recruitment rates.

- Recruitment of *Fucus serratus* from minute pelagic sporelings takes place from late spring until October. There is a reproductive peak in the period August - October and plants can be dispersed long distances (up to 10km). However, weak tidal streams probably results in a smaller supply of pelagic sporelings and most recruitment may come from local populations.
- *Fucus vesiculosus* gametes may be produced from mid winter until late summer with a peak of fertility in May and June. Eggs and sperm are released into the seawater and fertilised externally. Zygotes settle to the seabed and begin development wherever they fall. The egg becomes attached to the rock within a few hours of settlement and may adhere firmly enough to resist removal by the next returning tide.
- Visible *Chorda filum* sporophytes appear on shores between February and mid-March and develop into secondary sporophytes between April and June. The sporophytes are washed away from October to February, leaving behind zoospores or gametophytes.

### Time for community to reach maturity

Fucoid species are found on all British and Irish coasts so there are few mechanisms isolating populations. With the exception of *Ascophyllum nodosum* fucoids are highly fecund, iteroparous, surviving and breeding for protracted periods over 3-4 years. The eggs are broadcast into the water column allowing a potentially large dispersal distance. *Fucus serratus* and *Fucus vesiculosus* recruit readily to cleared areas, especially in the absence of grazers (Hawkins & Hartnoll, 1985). *Chorda filum* is an annual species reappearing every year so appearance of the species on cleared areas in suitable conditions will be possible within a year. Green algal species such as *Ulva* sp. and Ectocarpaceae are opportunistic ephemeral species that can recruit rapidly when conditions are suitable and will often be the early colonizers of areas that have been disturbed. Therefore, the time for the biotope community to reach maturity is likely to be only a few years although development of a stable community structure may take a little longer due to competitive interactions.

### Additional information

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### Preferences & Distribution

## Habitat preferences

<b>Depth Range</b>	0-5 m, 5-10 m
<b>Water clarity preferences</b>	
<b>Limiting Nutrients</b>	Nitrogen (nitrates), Phosphorus (phosphates)
<b>Salinity preferences</b>	Full (30-40 psu), Low (<18 psu), Reduced (18-30 psu)
<b>Physiographic preferences</b>	Enclosed coast / Embayment, Isolated saline water (Lagoon)
<b>Biological zone preferences</b>	Infralittoral, Sublittoral, Sublittoral fringe, Upper infralittoral
<b>Substratum/habitat preferences</b>	Bedrock, Cobbles, Gravel / shingle, Large to very large boulders, Pebbles, Sand, Small boulders
<b>Tidal strength preferences</b>	Moderately Strong 1 to 3 knots (0.5-1.5 m/sec.), Very Weak (negligible), Weak < 1 knot (<0.5 m/sec.)
<b>Wave exposure preferences</b>	Extremely sheltered, Sheltered, Very sheltered
<b>Other preferences</b>	

## Additional Information

## Species composition

Species found especially in this biotope

Rare or scarce species associated with this biotope

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## Additional information

## Sensitivity review

### Sensitivity characteristics of the habitat and relevant characteristic species

This biotope is characteristic of lagoon habitats. Saline lagoons are defined as areas of typically (but not exclusively) shallow, coastal saline water, wholly or partially separated from the sea by sandbanks, shingle or, less frequently, rocks or other hard substrata. They retain a proportion of their water at low tide and may develop as brackish, fully saline or hyper-saline water bodies (Brown *et al.*, 1997). There are only 358 examples of these rare and unusual habitats in the UK (Bamber *et al.*, 2001), which make up 5,184 hectares of coastline habitat (UKNEA, 2011). There are a number of factors which are thought to contribute to the rarity of these habitats in the UK. Many sedimentary lagoons do not appear in many of the areas suitable for them because of the macro-tidal regimes found within the north east Atlantic (Barnes, 1991). The high energy coastlines common around the UK mean that shingle lagoons can be both created from off-shore glacial deposits and removed, therefore they are often short lived on geological time scales, and are now less common than they were at the end of the last ice age (Bamber *et al.*, 2001). The low energy nature of lagoons also means that they can be susceptible to silting up which can elevate their basins above the level for percolation input. Perimeter shingle ridges elevated by storms, reduces water input via overtopping, and can cause lagoons to become freshwater lakes (Bamber *et al.*, 2001). The ephemeral nature of lagoons, and their susceptibility to change, means that the succession of habitats and consequently the biotopes found within them can be quicker and more noticeable than those found within other more stable physical environments.

This biotope is dominated by permanently submerged mixed fucoids (Connor *et al.*, 2004). The fucoids *Fucus vesiculosus* and *Fucus serratus* are the dominant fucoids species present. However, other macroalgae species such as *Ascophyllum nodosum* and *Chorda filum* can be present in addition to *Ulva* spp., *Mastocarpus stellatus*, *Polyides rotunda*, *Chondrus crispus*, *Ceramium* spp. and coralline crusts. The dominant grazing species within this biotope are littorinids. Other species present include the crab *Carcinus maenas*, mysid shrimps, and *Mytilus edulis*.

The characterizing species within this somewhat impoverished biotope are *Fucus vesiculosus* and *Fucus serratus*. These two macroalgae act as ecosystem engineers and the canopies that their fronds create modify habitat conditions. The canopy provides protection from desiccation for the various underlying seaweeds in addition to providing a substratum for epifauna and being the primary food resource for grazers. This can facilitate the existence and survival of other species and therefore strongly influencing the structure and functioning of ecosystems (Jenkins *et al.*, 2008). Within this biotope the physical feature of the lagoon also has the potential to be affected by some of the pressures at the given benchmarks. Therefore, this was also be taken into consideration during each assessment.

### Resilience and recovery rates of habitat

No evidence for the recovery rates of this biotope were found. The fucoids within the biotope can regrow damaged fronds and blades and may regrow from perennial holdfasts or crustose bases, where these remain. Where populations of animals and macroalgae are entirely removed (resistance is 'None') recovery will require recolonization by propagules. Adults of the mobile species present in the biotope, such as littorinids may recolonize through adult migration into the habitat from adjacent populations following disturbance or via larval recolonization. In general, the animals within the biotope, produce high numbers of pelagic larvae which are widely distributed by water currents, supporting recolonization from surrounding populations following

disturbances. Conversely the characterizing red and brown macroalgae generally have short dispersal distances (Dudgeon *et al.*, 2001). Recovery of algal populations may be rapid where adults remain but prolonged where populations are entirely removed.

*Fucus vesiculosus* growth rates can vary both spatially and temporally (Lehvo *et al.*, 2001). Temperature, exposure, and light availability are some of the factors which cause these changes in growth rates (Strömngren, 1977, Knight & Parke, 1950, Middelboe *et al.*, 2006). Strömngren (1977) investigated the effect of short-term increases in temperature on the growth rate of *Fucus vesiculosus*. It was found that the growth rate of the control sample kept at 7°C was 20 times lower than the sample introduced to temperatures of 35°C (Strömngren 1977). When the effect of temperature was investigated on the shore, relative growth rates in summer were found to be as high as 0.7% / day in summer, compared to less than 0.3% / day in winter (Lehvo *et al.*, 2001). In macroalgae, shorter individuals are found in situations with greater wave exposure (Lewis, 1961, Stephenson & Stephenson, 1972, Hawkins *et al.*, 1992, Jonsson *et al.*, 2006). For example, on Sgeir Bhuidhe, an exposed shore in Scotland, *Fucus vesiculosus* grew on average 0.31 cm / week. But, on a sheltered Scottish shore the average increased to 0.68 cm / week (Knight & Parke, 1950).

The development of the receptacles takes three months from initiation until when gametes are released (Knight, 1947). On British shores, receptacles are initiated around December and may be present until late summer (Knight, 1947). *Fucus vesiculosus* is dioecious, and gametes are generally released into the seawater under calm conditions (Mann, 1972; Serrão *et al.*, 2000) and the eggs are fertilized externally to produce a zygote. Serrão *et al.* (1997) determined that the wrack had short-range dispersal capacity. Under calm conditions in which eggs are released, most eggs fall in the immediate vicinity of the parent plants. The egg becomes attached to the rock within a few hours of settlement and adhere firmly enough to resist removal by the next returning tide and germling may be visible to the naked eye within a couple of weeks (Knight & Parke, 1950). Despite the poor long range dispersal, the species is highly fecund often bearing more than 1000 receptacles on each plant, which may produce in excess of one million eggs. On the coast of Maine, sampling on three separate occasions during the reproductive season revealed 100% fertilization on both exposed and sheltered shores (Serrão *et al.*, 2000). Fertilization is thus not considered as a limiting factor in reproduction in this species (Serrão *et al.*, 2000).

Mortality is extremely high in the early stages of germination up to a time when plants are 3 cm in length and this is due mostly to mollusc predation (Knight & Parke 1950). While *Fucus vesiculosus* may resist some degree of environmental stress, their long-term persistence depends on their reproductive ability as well as the survival and growth of early life history stages (germlings) that are generally more susceptible to natural and anthropogenic stressors than adults (Steen, 2004; Fredersdorf *et al.*, 2009). Consequently, it is necessary to include early life stage responses in the assessment of effects of environmental changes on fucoid algae (Nielsen *et al.*, 2014a).

In addition to sexual reproduction, *Fucus vesiculosus* is also able to generate vegetative re-growth in response to wounding. McCook & Chapman (1992) experimentally damaged *Fucus vesiculosus* holdfasts to test the ability of the wrack to regenerate. The study found that vegetative sprouting of *Fucus vesiculosus* holdfasts made a significant addition to the regrowth of the canopy, even when holdfasts were cut to less than 2 mm tissue thickness. Four months after cutting, sprouts ranged from microscopic buds to shoots about 10 cm long with mature shoots widespread after 12 months. Vegetative re-growth in response to wounding has been suggested as an important mean of recovery from population losses (McLachan & Chen, 1972). The importance of regeneration will depend on the severity of damage, not only in terms of the individuals but also in terms of the scale of canopy removal (McLachan & Chen, 1972).

*Fucus serratus* is perennial and reproduces annually over an extended period providing a good supply of potential recruits. Reproduction commences in late spring / early summer and continues through summer and autumn, peaking in August-October. Arrontes (1993) determined that the dispersal of *Fucus serratus* gametes and fertilized eggs was restricted to within 1–2 m from the parent. Average annual expansion rates for *Fucus serratus* populations have been estimated to be 0.3 to 0.6 km per year (Coyer *et al.*, 2006; Brawley *et al.*, 2009). Dispersal is highly limited as the negatively buoyant eggs are fertilized almost immediately after release and dispersal by rafting reproductive individuals is unlikely as the adults are not buoyant (Coyer *et al.*, 2006). However, *Fucus serratus* is found on all British and Irish coasts so there are few mechanisms isolating populations. While poor dispersal is true for medium or large spatial scales (hundreds of metres to kilometres), recruitment at short distances from parental patches is very efficient, as most propagules settle in the vicinity of parent plants (Arrontes, 2002). After experimental (small scale 2 m<sup>2</sup>) canopy removal of *Fucus serratus* on a moderately exposed shore, the *Fucus serratus* cover recovered within one year (Hawkins & Harkin, 1985). Similarly, after population crashes following eutrophication, Kraufvelin *et al.* (2006) observed the full recovery of a *Fucus serratus* canopy and animal community in less than 2 year after conditions returned to normal.

The red algae present in this biotope have complex life histories and exhibit distinct morphological stages over its reproductive life history. Alternation occurs between asexual spore producing stages (tetrasporophytes) and male and female plants producing sexually. Life history stages can be morphologically different or very similar. The tetrasporophyte phase of *Mastocarpus stellatus* is known as the petrocelis and is a flat crust, capable of growing laterally and covering extensive areas while the gametophyte has foliose blades. The gametophytes and tetrasporophytes of *Chondrus crispus*, in contrast, are relatively similar. The holdfasts of individual *Chondrus crispus* can, however, coalesce over time and form an extensive crust on rock (Taylor *et al.*, 1981). The basal crusts and crustose tetrasporophytes are perennial, tough, resistant stages that may prevent other species from occupying the rock surface and allow rapid regeneration. They may, therefore, provide a significant recovery mechanism. Where holdfasts and basal crusts are removed, recovery will depend on recolonization via spores. Norton (1992) reviewed dispersal by macroalgae and concluded that dispersal potential is highly variable, recruitment usually occurs on a much more local scale, typically within 10 m of the parent plant. Hence, it is expected that the algal turf would normally rely on recruitment from local individuals and that recovery of populations via spore settlement, where adults are removed, could be protracted. Minchinton *et al.* (1997) documented the recovery of *Chondrus crispus* after a rocky shore in Nova Scotia, Canada, was totally denuded by an ice scouring event. Initial recolonization was dominated by diatoms and ephemeral macroalgae, followed by fucoids and then perennial red seaweeds. After 2 years, *Chondrus crispus* had re-established approximately 50% cover on the lower shore and, after five years, it was the dominant macroalga at this height, with approximately 100% cover.

'Coralline crust' is a generic term in UK biotopes that refers to nongeniculate (crustose) species from the family Corallinacea, and could include *Lithophyllum incrustans* which is noted to form thick crusts in tidepools, especially in the south west (Adey & Adey, 1973). Although ubiquitous in marine coastal systems little is understood about the taxonomy, biology and ecology of this taxa (Littler & Littler, 2013). Throughout the sensitivity assessments the term coralline crust is used to refer to the Corallinacea that occur within the biotope. Due to the lack of evidence for species the assessments are generic, although species specific information is presented where available. A number of papers by Edyvean & Ford (1984a & b; 1986; 1987) describe aspects of reproduction and growth of encrusting coralline, *Lithophyllum incrustans*. Studies by Edyvean & Forde (1987) on populations of *Lithophyllum incrustans* in Pembroke south-west Wales suggest that reproduction occurs on average early in the third year. Reproduction may be sexual or asexual. Populations

release spores throughout the year but spore abundance varies seasonally. Spore survival is extremely low with only a tiny proportion of spores eventually recruiting to the adult population (Edyvean & Ford, 1986). Edyvean & Ford (1984a) found that the age structure of populations sampled from Orkney (Scotland) Berwick (northern England) and Devon (England) were similar, mortality seemed highest in younger year classes with surviving individuals after the age of 10 years appear relatively long-lived (up to 30 years). In St Mary's Northumberland, the population was dominated by the age 6-7 year classes (Edyvean & Ford, 1984a). Growth rates were highest in young plants measured at Pembroke (south-west Wales) with an approximate increase in diameter of plants of 24 mm in year class 0 and 155 mm in year 1 and slowing towards an annual average horizontal growth rate of 3 mm / year (Edyvean & Ford, 1987). Some repair of damaged encrusting coralline occurs through vegetative growth. Chamberlain (1996) observed that, although *Lithophyllum incrustans* was quickly affected by oil during the *Sea Empress* spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area. Recolonization by propagules is an important recovery mechanism. Airoidi (2000) observed that encrusting coralline algae recruited rapidly on to experimentally cleared subtidal rock surfaces in the Mediterranean Sea, reaching up to 68% cover in 2 months. As encrusting corallines are sensitive to desiccation (Dethier, 1994) it should be noted that this infralittoral habitat is probably more favourable for recruitment, growth and survival than intertidal rock pools.

Other species associated with this biotope, including the littorinids, exhibit episodic recruitment. Where individuals are removed from a small area, adult littorinids may recolonize from surrounding patches of habitat where these are present. The littorinids associated with this biotope 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. Changes and recovery trajectories following the removal of species are unpredictable and interactions between the characterizing and associated species may be positive or negative. Due to species interactions, recovery trajectories cannot be predicted by life history characteristics alone.

Genetic diversity can influence the resilience of fucoids in particular when pressure persists over a long period of time. Genetically diverse populations are generally more resilient to changes in environmental conditions compared to genetically conserved populations. Tatarenkov *et al.* (2007) determined a high level of genetic variation in *Fucus vesiculosus* and extensive phenotypic variation. This could explain why the species is more successful than most fucoid species in colonizing marginal marine environments such as low-salinity estuaries as it shows a range of morphological, physiological and ecological adaptations (Tatarenkov *et al.* 2005). Pressures causing a rapid change will have a greater impact as the natural ability of the species to adapt is compromised.

Lagoons are rare within the UK and, on geological timescales, are short lived coastal features. Spencer & Brooks (2012) state that over decadal timescales, the seaward barriers that enclose saline lagoons migrate progressively landwards naturally. This is part of the natural succession of the habitat. However, these seaward barriers will move even faster if local geomorphological conditions change. A change in geomorphological conditions could both speed up the movement of the lagoon landwards, and change the supply of sediment to the barrier. Ultimately this could lead to the total removal of the barrier and the loss of the lagoon. The effects of an artificial structure built behind a lagoon must also be taken into consideration. It is possible that such a structure could potentially inhibit the natural migration of the lagoon landwards, and thus reduce the lifespan of the lagoon.

**Resilience assessment.** If specimens of *Fucus vesiculosus* remain in small quantities it is likely that re-growth will occur rapidly due to efficient fertilization rates and recruitment over short distances. The ability of *Fucus vesiculosus* to re-grow from damaged holdfasts will also aid in recolonization. *Fucus serratus* has the ability to recolonize areas quickly. With evidence for populations of *Fucus serratus* recovering within two years of a disturbance event. The mobile nature of littorinids that they can recolonize areas quickly by moving into them. The good dispersal potential of their larvae will also aid recolonization of shores.

It must be considered that the location of this biotope within lagoon habitats will limit the ability of this biotope to be quickly recolonized. The low flushing times and high water retention rates within saline lagoons means that larva and propagule supply will also be slow. Recovery of this biotope is likely to occur within two years as long some of the characterizing species from the biotope remain, or there are other populations of the species within the lagoon. This scenario results in a 'High' resilience score. However, if there are no adjacent populations and the biotope is completely removed (resistance is 'None'), recovery may take longer, perhaps up to ten years so the resilience would be scored as 'Medium'.

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

## Hydrological Pressures

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

Schonbeck & Norton (1979) demonstrated that furoids can increase tolerance in response to gradual change in temperature through a process known as 'drought hardening'. However, acute changes in temperatures may cause damage to macroalgae and other species. Temperature ranges of species may not accurately describe their ability to withstand localized changes in temperature. Yet they will display the limits of the species genetic ability to acclimatize to temperatures. Juvenile life stages of organisms can be less tolerant to environmental conditions than more mature stages.

Most furoids are cold-temperate species (Lüning, 1984), and temperatures above 20 °C are generally considered unsuitable for these algae (Zou *et al.*, 2012). The effect of high temperature stress on photosynthesis in brown algae is related to inactivation of enzymes and the induction of reactive oxygen species (ROS), leading to photoinhibition (Suzuki & Mittler, 2006). Growth rates of adult brown macroalgae may be affected by temperature through the increase in metabolic rates (Nygard & Dring, 2008).

In the north east Atlantic, *Fucus vesiculosus* occurs from Northern Russia to Morocco (Powell,

1963). *Fucus vesiculosus* is able to tolerate temperatures as high as 30 °C (Lüning, 1990) and did not show any sign of damage during the extremely hot UK summer of 1983, when average temperatures were 8 °C hotter than normal (Hawkins & Hartnoll, 1985). *Fucus vesiculosus* also tolerates extended periods of freezing in the northern part of its range.

*Fucus serratus* is found along the Atlantic coast of Europe from Svalbard to Portugal and on the shores of north-east America. The seaweed is thus well within its thermal range in the British Isles. Nielsen *et al.* (2014b) found no negative effects on growth rates of adult *Fucus serratus* to water temperatures of 22 °C (based on a laboratory experiment with specimen collected from Firth of Forth, Scotland). Arrontes (1993) observed that *Fucus serratus* survived in laboratory experiments for 1 week at 25 °C. Nielsen *et al.* (2014b) did, however, report that germlings were negatively affected by increased temperature indicating that early life stages are more vulnerable than mature algae to this pressure.

Several studies have observed adverse effects of *Fucus serratus* as a result of warm thermal stress in terms of growth, physiological performance and reproductive output in Spain and Portugal (Pearson *et al.*, 2009; Viejo *et al.*, 2011; Martínez *et al.*, 2012). Jueterbock *et al.* (2014) determined that these negative impacts can be explained by restricted within-population genetic diversity. South west Ireland and Brittany are hot-spots of genetic diversity with *Fucus serratus* (Coyer *et al.*, 2003; Hoarau *et al.*, 2007) and may thus be more resilient to changes in temperature. Phenotypic plasticity therefore plays an important role in determining the sensitivity of individual populations to changes in temperature.

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). *Ulva* spp. are characteristic of upper shore rock pools, where water and air temperatures are greatly elevated on hot days and replace the brown algae where temperatures are increased for longer periods (exceeding the pressure benchmark).

In an exceptionally hot summer (1983, with an increase of between 4.8 and 8.5 °C), Hawkins & Hartnoll (1985) recorded that understory red algae showed more signs of damage than canopy forming species, with bleached *Corallina officinalis* observed around the edges of pools due to desiccation. Occasional damaged specimens of *Palmaria palmata*, *Osmundea pinnatifida* and *Mastocarpus stellatus* were also observed. The median upper lethal temperature limit in laboratory tests on *Littorina littorea* and *Littorina saxatilis* was approximately 35 °C (Davenport & Davenport, 2005).

**Sensitivity assessment.** An increase in temperature at the pressure benchmark is not likely to have a detrimental effect on this biotope and its associated community, based on global distribution. Phenotypic plasticity will influence the tolerance of individual population. Some of the understory of red algae may be lost during acute temperature increases if these occur in the summer when plants are already close to the limit of thermal tolerances. Biotope resistance is assessed as 'High' and resilience as 'High' and the biotope is considered to be 'Not sensitive'. It should be noted that the timing of acute and chronic increases would alter the degree of impact and hence sensitivity. An acute change occurring on the hottest days of the year and exceeding thermal tolerances may lead to mortality.

**Temperature decrease (local)****High**

Q: High A: Medium C: Medium

**High**

Q: High A: Medium C: Medium

**Not sensitive**

Q: High A: Medium C: Medium

Schonbeck & Norton (1979) demonstrated that fucooids can increase tolerance in response to gradual change in temperature through a process known as 'drought hardening'. However, acute changes in temperatures may cause damage to macroalgae and other species. Temperature ranges of species may not accurately describe their ability to withstand localized changes in temperature. Yet they will display the limits of the species genetic ability to acclimatize to temperatures. Juvenile life stages of organisms can be less tolerant to environmental conditions than more mature stages.

Lüning (1990) suggested that most littoral algal species were tolerant of cold and freezing. Lüning (1984) reported that *Fucus serratus* survived in the laboratory for a week a range temperature between 0°C and 25°C. *Fucus serratus* is found along the Atlantic coast of Europe from Svalbard to Portugal and on the shores of north-east America and is therefore within its thermal range in the British Isles.

In the North-East Atlantic, *Fucus vesiculosus* occurs from Northern Russia to Morocco (Powell, 1963). This distribution suggests that *Fucus vesiculosus* tolerates extended periods of freezing during winter in the norther part of its range.

*Mastocarpus stellatus* and *Chondrus crispus* have a broad geographical distribution (Guiry & Guiry, 2015) and throughout the range experience wide variation in temperatures (although local populations may be acclimated to the prevailing thermal regime). The photosynthetic rate of *Mastocarpus stellatus* higher on the shore fully recovered from 24 hrs at -20 °C (Dudgeon *et al.* (1989). Photosynthesis in *Mastocarpus stellatus* also recovered quickly after experimental freezing (Dudgeon *et al.*, 1989, 1995). Davenport & Davenport (2005) found that the median lower lethal temperature tolerances for *Littorina saxatilis* and *Littorina littorea* were -16.4 and -13°C respectively.

**Sensitivity assessment.** A decrease in acute or chronic temperature above average British and Irish temperatures is not likely to have a detrimental effect on *Fucus vesiculosus* or *Fucus serratus* and associated communities, based on global distribution. However, it should be noted that phenotypic plasticity and acclimation will influence the tolerance of individual population. 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)****Low**

Q: High A: Medium C: Medium

**High**

Q: High A: Medium C: Medium

**Low**

Q: High A: Medium C: Medium

Variation in salinity within saline lagoons is a characteristic of lagoonal habitats. In larger lagoons it is also possible to get different salinity regimes within different areas of the lagoon. Therefore, all species found within saline lagoon communities must be able to tolerate salinity fluctuations. All lagoons are affected by short, medium and long-term changes in salinity (Bamber *et al.*, 2001). Semi-diurnal tides cause differences in salinity over short periods, changes in rainfall can cause the

medium term changes and seasonal rainfall and drought can cause longer term salinity trends (Bamber *et al.*, 2001). Intertidal macroalga, such as those found within this biotope, often experience large but short-term changes in salinities (Lobban & Harrison, 1997). However, the tolerance of intertidal macroalgae to longer term changes in salinities can be minimal and can quickly reduce photosynthetic abilities and cause mortality. This biotope is only found in variable salinity conditions (18 – 40 psu) (Connor *et al.*, 2004), an increase in the salinity would create fully marine conditions (30 – 40 psu).

A number of biotopes dominated by the same characterizing species and with many of the associated species occur in fully marine habitats. Within these fully marine biotopes, species abundances are greater and species richness is higher, as the habitat conditions are closer to optimal for a wider range of species. The assessed biotope could be considered an impoverished example of these biotopes, as the stress induced by variable salinity leads to reduced growth and lower species richness and diversity.

Investigations into the salinity tolerances of *Fucus vesiculosus* in laboratory controlled conditions found that the photosynthetic capabilities of both species decreased with reduced salinities (Connan & Stengel, 2011). *Fucus vesiculosus* well adapted to cope with varying salinities and can grow in full saline to brackish conditions. Indeed *Fucus vesiculosus* is the dominant large perennial seaweed in the Baltic Sea growing in salinities down to 4 psu (Kautsky, 1992). Bäck *et al.* (1991) compared *Fucus vesiculosus* individuals from Atlantic and the Baltic populations. Both populations were able to withstand wide range of salinities in laboratory cultures, yet some differences were recorded. The Atlantic population showed better growth in higher salinities and virtually no growth at 5 ppt. Those individuals kept at 5 ppt mortality occurred after 7 weeks. In contrast the Baltic wracks grew better in conditions with lower salinities. Growth was negligible at the highest tested salinity (45 ppt). Bäck *et al.* (1991) demonstrate that sensitivity of *Fucus vesiculosus* to changes in salinity differ between populations.

Serrao *et al.* (1996a) found that lower salinities can negatively affect both the fertilization rates and recruitment success of *Fucus vesiculosus*. Serrao *et al.* (1996a) also concluded that the osmotic tolerances of *Fucus vesiculosus* gametes limit the species distribution in the Baltic Sea. These studies show that low salinities limit the recruitment and fertilization success of fucoids. There is also evidence suggesting that reduced salinities can influence the rate of receptacle maturation in fucoids (Munda, 1964). Rate of fructification in *Fucus vesiculosus* has been measured to increase in diluted seawater (Munda, 1964).

**Sensitivity assessment.** The characterizing and associated species occur in fully marine habitats. The biotope, however, is specifically described as occurring in variable salinity and to be structured by this factor. A change in conditions would be likely to lead to increased abundance of characterizing species, particularly *Fucus vesiculosus* and *Fucus serratus*, coupled with increased species richness. The biotope character would therefore be likely to change: biotope resistance is therefore assessed as 'Low' and resilience as 'High', following a return to a variable salinity regime (as the characterizing and associated species would be present). Biotope sensitivity is, therefore, assessed as 'Low'.

#### Salinity decrease (local)

Low

Q: High A: Medium C: Medium

High

Q: High A: Medium C: Medium

Low

Q: High A: Medium C: Medium

Variation in salinity within saline lagoons is a characteristic of the habitat that they create. In larger lagoons it is also possible to get different salinities within different areas of the lagoon itself.

Therefore, all species found within saline lagoon communities must be able to tolerate salinity fluctuations. All lagoons are affected by short, medium and long-term changes in salinity (Bamber *et al.*, 2001). Semi-diurnal tides cause differences in salinity over short periods, response to changes in rainfall can cause the medium term changes, and seasonal rainfall and drought can cause longer term salinity trends (Bamber *et al.*, 2001). Intertidal macroalgae, such as those found within this biotope, often experience large but short-term changes in salinities (Lobban & Harrison, 1997). However, intertidal macroalgae tolerances to longer term changes in salinities can be minimal and can quickly reduce photosynthetic abilities and cause mortality. This biotope is only found in variable salinity conditions (18 – 40 psu) (Connor *et al.*, 2004). Local populations may be acclimated to the prevailing salinity regime and may exhibit different tolerances to other populations subject to different salinity conditions. Consequently, caution should be used when inferring tolerances from populations in different regions. The plant and animal assemblage within this biotope is relatively impoverished compared with similar biotopes present in full salinity (Connor *et al.*, 2004). At the pressure benchmark a decrease refers to a change in salinity regime to low (< 18 ppt).

Fucoids are able to compensate for changes in salinity by adjusting internal ion concentrations. However, this will occur at a cost, reducing photosynthetic rate and hence affecting the growth rate of the seaweed. Growth rates for *Fucus serratus* are maximal at a salinity of 20 psu with the critical limit for recruitment set at 7 psu (Malm *et al.*, 2001). Sufficient salinity is essential for successful fertilization and germination in *Fucus* (e.g., Brawley, 1992a; Serrão *et al.*, 1999). Malm *et al.* (2001) found that fertilization success in *Fucus serratus* decreased substantially with strongly reduced salinity. Indeed the study found that fertilisation success was 87% at 9 psu but declined to 5% at 6 psu (Malm *et al.*, 2001). Reduced salinity does also affect dispersal by decreasing swimming performance of fucoid sperm (Serrão *et al.*, 1996).

Laboratory controlled conditions found that the photosynthetic capabilities of *Fucus vesiculosus* decreased with reduced salinities (Connan & Stengel, 2011). *Fucus vesiculosus* is well adapted to cope with varying salinities and can grow in full saline to brackish conditions. Indeed *Fucus vesiculosus* is the dominant large perennial seaweed in the Baltic Sea growing in salinities down to 4 psu (Kautsky, 1992). Bäck *et al.* (1991) compared *Fucus vesiculosus* individuals from Atlantic and the Baltic populations. Both populations were able to withstand wide range of salinities in laboratory cultures, yet some differences were recorded. The Atlantic population showed better growth in higher salinities and virtually no growth at 5 ppt. Those individuals kept at 5 ppt mortality occurred after 7 weeks. In contrast the Baltic wracks grew better in conditions with lower salinities. Bäck *et al.* (1991) demonstrate that sensitivity of *Fucus vesiculosus* to changes in salinity differ between populations.

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

A decrease in salinity may lead to replacement of more sensitive red algal turf forming species by those more tolerant of the changed conditions. *Chondrus crispus* occurs in areas of 'low' salinity. For example, the species occurs in estuaries in New Hampshire, USA, where surface water salinity

varies from 16-32 psu (Mathieson & Burns, 1975). Mathieson & Burns (1971) recorded maximum photosynthesis of *Chondrus crispus* in culture at 24 psu, but rates were comparable at 8, 16 and 32 psu. Tasende & Fraga (1999) cultured *Chondrus crispus* spores from north west Spain and concluded that growth was correlated with salinity between 23 and 33 psu. *Littorina littorea* is found in waters of full, variable and reduced salinities (Connor *et al.*, 2004).

*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 (Alström-Rapaport *et al.*, 2010; Reed & Russell 1979). A salinity decrease at the pressure benchmark may lead to a shift to a biotope dominated by *Ulva* spp.

**Sensitivity assessment.** The change in salinity at the pressure benchmark is interpreted as a change to a more stable salinity regime with salinity constantly lowered below 18 ppt. Most of the literature found on this topic considered short-term (days to weeks) impacts of changes to salinity whilst the benchmark refers to a change for one year. Prolonged reduction in salinity at the pressure benchmark is likely to reduce growth rates, species abundance and species richness as less tolerant species and individuals are lost. Some species replacements are likely as *Ulva* spp. may colonize the biotope, while *Fucus vesiculosus*, *Fucus serratus* and red seaweeds are likely to decrease in abundance or be out-competed. Biotope resistance is assessed as 'Low' as changes in species composition and abundances are expected. Resilience is assessed as 'High' (following a return to reduced salinity), as some of the characterizing species may survive, so that biotope sensitivity is assessed as 'Low'.

#### Water flow (tidal current) changes (local)

**High**

Q: High A: Medium C: Medium

**High**

Q: High A: Medium C: Medium

**Not sensitive**

Q: High A: Medium C: Medium

This biotope has weak to very weak water flow conditions. An increase in water flow may cause an increase in the level of erosion of the sea barrier. This could consequently lead to the loss collapse of a lagoon wall and completely change the physical environment of the biotope, and lead to the loss of the lagoon biotope altogether.

Water motion is a key determinant of marine macroalgal ecology, influencing physiological rates and community structure (Hurd, 2000). Higher water flow rates increase mechanical stress on macroalgae by increasing drag. Fucooids are highly flexible but not physically robust and an increase in water flow could cause mechanical damage, breaking fronds or even dislodging whole algae from the substratum. Fucooids are however, highly flexible and are able to re-orientate their position in the water column to become more streamlined. This ability allows fucooids to reduce the relative velocity between algae and the surrounding water, thereby reducing drag and lift (Denny *et al.*, 1998). Fucooids are permanently attached to the substratum and would not be able to re-attach if removed. Organisms living on the fronds and holdfasts will be washed away with the algae whereas free-living community components could find new habitat in surrounding areas. Wave exposure has been shown to limit size of fucooids (Blanchette, 1997) as smaller individuals create less resistance to water movement.

The presence of this biotope within conditions with minimal tidal flow suggests that there is unlikely to be a negative impact of a decrease in the mean spring bed flow velocity of 0.2m/s. Yet some water flow is required to supply vital nutrients and gases and to remove waste products. If the reduction meant that water flow stopped all together then the biotope may suffer negative impacts, due to stagnant conditions.

An increase in this pressure at the bench mark rate within a biotope which is already found at the top of the tolerance for water flows may be negatively affected. The highest water flow that would be created within this biotope taking into consideration the level of the benchmark is 0.7 m/s. This flow rate is not high enough to remove the two characterizing species.

*Fucus vesiculosus* individuals of 10 cm or larger have been recorded to be completely removed at 7-8 m/s (Jonsson *et al.*, 2006). A much greater flow rate than what is experienced at the extreme end of this benchmark within this biotope. Thomson & Wernberg (2005) provide strong evidence that with an increase in thallus size there is an increase in the break force required to remove algae. This evidence suggests that the characterizing macroalgae populations are unlikely to be torn from the substratum at the level of this bench mark. The risk of dislodgement would only be greater where algae are attached to pebbles instead of bedrock. Indeed if sediment type is small and the substratum is less stable, individuals may eventually reach a critical size when the drag force exceeds gravity and the plant will be moved together with its substratum (Malm, 1999). This risk is increased during the late phase of reproduction for *Fucus vesiculosus* when its receptacles become swollen and gas-filled increasing the uplifting force of water flow (Isaeus, 2004).

*Littorina littorea* is found in areas with water flow rates from negligible to strong, although populations exposed to different levels of flow may have adapted to local conditions. Increases in water flow rates above 6 knots may cause snails in less protected locations (e.g. not in crevices etc.) to be continually displaced into unsuitable habitat so that feeding may become sub-optimal. Shell morphology within littorinids varies according to environmental conditions, in sheltered areas, where *Carcinus maenas* is more prevalent, shell apertures are small to inhibit predation. In exposed areas the foot surface is larger to allow greater attachment and the shell spire is lower to reduce drag (Raffaelli 1982, Crothers, 1992).

**Sensitivity assessment.** This biotope is only found in very weak water flow conditions. An increase in water flow at the benchmark is unlikely to have a significant negative effect on the biological composition of the biotope. Based on the available evidence, the characterizing species and associated macroalgae and animals are able to adapt to high flow rates. Both the resilience and resistance have been assessed as 'High' resulting in a 'Not sensitive' sensitivity assessment. A change in the water flow at the pressure benchmark is unlikely to cause the loss of the lagoon biotope. However, an increase in this pressure above the given benchmark (e.g. storms or floods) has the possibility of removing the lagoon completely.

### Emergence regime changes

**Low**

Q: High A: Medium C: Medium

**High**

Q: High A: Medium C: Medium

**Low**

Q: High A: Medium C: Medium

Changes in emergence can lead to greater exposure to desiccation, temperature and salinity, and reduced levels of time for filter feeding, nutrient uptake, and photosynthesis. Changes in emergence can also alter competitive interactions and trophic interactions such as grazing and predation. Environmental factors partly set upper and lower limits of algal distribution on shores. Spores and developing germlings are particularly susceptible to desiccation as they have very large surface-to-volume ratios, although they benefit from the film of water that persists in concavities on the substratum (Kain & Norton, 1990). At higher shore levels red algae tend to occur only under canopy forming species, as these limit exposure to desiccation (Hawkins and Hartnoll, 1983).

*Fucus serratus* is more susceptible to desiccation than other *Fucus* species that are located further up the shore and subjected more frequently to aerial exposure (Schonbeck & Norton, 1978). In

experiments *Fucus serratus* did not survive transplantation further up the shore, e.g. in the *Fucus spiralis* belt (Schonbeck & Norton, 1978). The critical water content for *Fucus serratus* is estimated at 40% with water losses past this point causing irreversible damage. Beer *et al.* (2014) found that *Fucus serratus* could not regain any positive photosynthetic rates after rehydrating from 10% water content. The upper shore extent of *Fucus serratus* populations may be replaced by species more tolerant of desiccation and more characteristic of the mid-eulittoral such as *Fucus vesiculosus* or *Ascophyllum nodosum*.

*Fucus vesiculosus* can tolerate desiccation until the water content is reduced to ~ 30%. If desiccation occurs beyond this level, irreversible damage occurs. Individuals at the top of the shore probably live at the upper limit of their physiological tolerance and therefore are likely to be unable to tolerate increased desiccation and would be displaced by more physiologically tolerant species. Tolerance to this pressure is likely to vary on a geographical scale. Gylle *et al.* (2009) found that *Fucus vesiculosus* populations naturally occurring in fully saline conditions had a higher emersion stress tolerance compared to brackish populations.

Early life history stages are more susceptible to this pressure compared to adults (Henry & Van Alstyne, 2004). Germlings are however, protected from desiccation by the canopy of adults. A study by Brawley & Johnson (1991) showed that germling survival under adult canopy was close to 100% whereas survival on adjacent bare rock was close to 0% during exposure to aerial conditions. The *Fucus* canopy is also likely to protect other underlying species to a great extent.

Occurrence of encrusting coralline algae seems to be critically determined by exposure to air and sunlight. Colonies survive in damp conditions under algal canopies or in pools but not on open rock where desiccation effects are important. Increased emergence leading to drying out of shallow pools would reduce habitat suitability for this group. Spore release by the crusting coralline *Lithophyllum incrustans* is triggered by small changes in salinity and temperature and, therefore, changes in emergence may alter patterns in reproduction and recruitment (see relevant pressures for further information). However, this species can occur both high and low in the intertidal (Edyvean & Ford, 1986) and presumably such impacts are limited. In this impoverished biotope, however, the canopy cover may be too sparse to support encrusting corallines higher on the shore.

**Sensitivity assessment:** This biotope is somewhat unusual because it is permanently submerged (Conner *et al.*, 2004), yet the species within it are characteristic of intertidal habitats. As all of the characterizing and associated species within this biotope can be found in intertidal biotopes, an increase in emergence would not create environmental conditions intolerable to these species. However, the conditions required for this biotope would no longer present. The resistance has been assessed as low, and resilience as 'High'. This results in an overall sensitivity of 'Low'.

#### Wave exposure changes (local)

High

Q: High A: Medium C: Medium

High

Q: High A: Medium C: Medium

Not sensitive

Q: High A: Medium C: Medium

This biotope is found in extremely wave sheltered conditions. An increase in wave exposure at the benchmark is unlikely to have a significant negative effect on the biological composition of the biotope. However, it must be assumed that if there is an increase in the water flow within the biotope there will also be an increase in the water flow around the lagoon. An increase in water flow at the benchmark is unlikely could have a detrimental effect on the structure of the lagoon through erosion. However, if water flow were to increase above the given benchmark then it is

possible that water flow cause an increase in the level of erosion of the sea barrier. This could consequently lead to the loss collapse of a lagoon wall and completely change the physical environment of the biotope, and lead to the loss of the lagoon biotope altogether.

Water motion is a key determinant of marine macroalgal ecology, influencing physiological rates and community structure (Hurd, 2000). Higher water flow rates increase mechanical stress on macroalgae by increasing drag. Furoids are highly flexible but not physically robust and an increase in water flow could cause mechanical damage, breaking fronds or even dislodging whole algae from the substratum. Furoids are however, highly flexible and are able to re-orientate their position in the water column to become more streamlined. This ability allows furoids to reduce the relative velocity between algae and the surrounding water, thereby reducing drag and lift (Denny *et al.*, 1998). Furoids are permanently attached to the substratum and would not be able to re-attach if removed. Organisms living on the fronds and holdfasts will be washed away with the algae whereas free-living community components could find new habitat in surrounding areas. Wave exposure has been shown to limit size of furoids (Blanchette, 1997) as smaller individuals create less resistance to water movement, it is likely that water flow exerts a very similar pressure on furoids.

The presence of this biotope within conditions with minimal tidal flow suggests that there is unlikely to be a negative impact of a decrease in the mean spring bed flow velocity of 0.2m/s in flow rate. Yet some water flow is required to supply vital nutrients and gases and to remove waste products. If the reduction meant that water flow stopped all together then the biotope may suffer negative impacts, due to stagnant conditions.

An increase in this pressure at the bench mark rate within a biotope which is already found at the top of the tolerance for water flows may be negatively affected. The highest water flow that would be created within this biotope taking into consideration the level of the benchmark is 0.7 m/s. This flow rate is not high enough to remove the two characterizing species.

*Fucus vesiculosus* individuals of 10cm or larger have been recorded to be completely removed at 7-8m/s (Jonsson *et al.*, 2006). A much greater flow rate than what is experienced at the extreme end of this benchmark within this biotope. This evidence suggests that the characterizing macroalgae populations are unlikely to be torn from the substrate at the level of this bench mark. The risk of dislodgement would only be greater where algae are attached to pebbles instead of bedrock. Indeed if sediment type is small and the substratum is less stable, individuals may eventually reach a critical size when the drag force exceeds gravity and the plant will be moved together with its substratum (Malm, 1999). This risk is increased during the late phase of reproduction for *Fucus vesiculosus* when its receptacles become swollen and gas-filled increasing the uplifting force of water flow (Isaeus, 2004).

Propagule dispersal, fertilization, settlement, and recruitment are also influenced by water movement (Pearson & Brawley, 1996). An increase in the mean water flow will reduce the time during which attachment is possible. In addition, greater water flow can increase scour through increased sediment movement. Small life stages of macroalgae are likely to be affected by removing new recruits from the substratum and hence reducing successful recruitment (Devinny & Vorse, 1978) (see 'siltation' pressures). Changes in water motion can thus strongly influence local distribution patterns of *Fucus* spp. (Ladah *et al.*, 2008).

On the other hand, a reduction in water flow can cause a thicker boundary layer resulting in lower absorption of nutrients and CO<sub>2</sub> by the macroalgae. Slower water movement can also cause

oxygen deficiency directly impacting the fitness of algae (Olsenz, 2011).

**Sensitivity assessment.** A change in the water flow at the pressure benchmark is unlikely to cause the loss of the lagoon biotope. However, an increase in this pressure above the given benchmark has the possibility of removing the lagoon completely. A decrease in water flow could reduce the removal of waste products and the return of nutrients and gases. For this reason biotopes which experience the lowest levels of water flow naturally may be more affected than those found in areas with more water movement. However, this is unlikely to cause any mass mortality, more a decrease in the health of the biotope. An increase in the level of water flow would be more likely to affect the reproductive and recruitment success of the species. Again this would not cause a mass mortality, but more a decrease in the health of the biotope. The resistance and resilience have been assessed as 'High'. This gives the biotope an overall sensitivity of 'Not Sensitive'.

## Chemical Pressures

	Resistance	Resilience	Sensitivity
<b>Transition elements &amp; organo-metal contamination</b>	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.

<b>Hydrocarbon &amp; PAH contamination</b>	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR
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This pressure is **Not assessed** but evidence is presented where available.

<b>Synthetic compound contamination</b>	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR
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This pressure is **Not assessed** but evidence is presented where available.

<b>Radionuclide contamination</b>	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR
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No evidence.

<b>Introduction of other substances</b>	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR
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This pressure is **Not assessed**.

<b>De-oxygenation</b>	High Q: Medium A: Medium C: Medium	High Q: High A: Medium C: Medium	Not sensitive Q: Medium A: Medium C: Medium
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Reduced oxygen concentrations have been shown to inhibit both photosynthesis and respiration in macroalgae (Kinne, 1977). Despite this, macroalgae are thought to buffer the environmental conditions of low oxygen, thereby acting as a refuge for organisms in oxygen depleted regions especially if the oxygen depletion is short-term (Frieder *et al.*, 2012). Reduced oxygen levels are likely to inhibit respiration whilst immersed, but it is unlikely to cause a loss of the macroalgae population directly.

Although the macroalgae species within this biotope may not be negatively affected some of the associated fauna may be lost, causing a reduction in species richness. Josefson & Widbom (1988) investigated the response of benthic macro and meiofauna to reduced dissolved oxygen levels in the bottom waters of a fjord. At dissolved oxygen concentrations of 0.21 mg/l, the macrofaunal community was eradicated and was not fully re-established 18 months after the hypoxic event. Meiofauna seemed however unaffected by de-oxygenation. Mobile species will be able to relocate to more optimal conditions, whereas immobile species such as barnacles are likely to be put under more stress by de-oxygenation.

The extremely wave sheltered conditions and the weak to very weak water flows which are characteristic of this biotope mean that water mixing is not very strong. Water retention rates within lagoons are also known to be high, with very low flushing times. Therefore water movement within this area will not reverse any oxygen depletion quickly, possibly exacerbating any negative effects.

**Sensitivity assessment.** The characterizing species *Fucus vesiculosus* and *Fucus serratus* would suffer significant mortalities by a decrease in oxygen within the water column for at the benchmark level of this pressure. However, it is possible that some of the associated fauna may be negatively affected by the decrease in oxygen. Mobile species such the Littorinids would relocate to conditions that were less physiologically taxing, and would be able to return when the pressure abated. The very low levels of water movement within the biotope habitat slow down the re-oxygenation of this biotope after the pressure event. Resistance is assessed as 'High', as it the resilience. The biotope sensitivity is 'Not sensitive'.

#### Nutrient enrichment

High

Q: Medium A: Medium C: Medium

High

Q: High A: Medium C: Medium

Not sensitive

Q: Medium A: Medium C: Medium

The nutrient enrichment of a marine environment leads to organisms no longer being limited by the availability of certain nutrients. The consequent changes in ecosystem functions can lead to the progression of eutrophic symptoms (Bricker *et al.*, 2008), changes in species diversity and evenness (Johnston & Roberts, 2009) decreases in dissolved oxygen and uncharacteristic microalgae blooms (Bricker *et al.*, 1999, 2008).

Johnston & Roberts (2009) undertook a review and meta analysis of the effect of contaminants on species richness and evenness in the marine environment. Of the 47 papers reviewed relating to nutrients as a contaminants, over 75% found that it had a negative impact on species diversity, <5% found increased diversity, and the remaining papers finding no detectable effect. Of the 47 papers none considered the impact of nutrients on lagoons. Yet this finding is still relevant to this biotope as the meta analysis revealed that the effect of marine pollutants on species diversity were 'remarkably consistent' between habitats (Johnston & Roberts, 2009). It was found that any single pollutant reduced species richness by 30-50% within any of the marine habitats considered (Johnston & Roberts, 2009). Throughout their investigation there were only a few examples where species richness was increased due to the anthropogenic introduction of a contaminant.

These examples were almost entirely from the introduction of nutrients, either from aquaculture or sewage outfalls. However, research into the impacts of nutrient enrichment from these sources on intertidal rocky shores often lead to shores lacking species diversity and the domination by algae with fast growth rates (Abou-Aisha *et al.*, 1995, Archambault *et al.*, 2001, Arévalo *et al.*, 2007, Diez *et al.*, 2003, Littler & Murray, 1975). The lagoon habitat within which this biotope is found is not studied within this paper. However, the characterizing species are most commonly found on intertidal rocky shores and therefore this statement has been considered to be relevant to this assessment.

Major declines of *Fucus vesiculosus* have been reported from all over the Baltic Sea. These declines have been associated to eutrophication from nutrient enrichment (Kautsky *et al.*, 1986). Nutrient enrichment alters the selective environment by favouring fast growing, ephemeral species such as *Ulva lactuca* and *Ulva intestinalis* (Berger *et al.*, 2004, Kraufvelin, 2007). Rohde *et al.*, (2008) found that both free growing filamentous algae and epiphytic microalgae can increase in abundance with nutrient enrichment. This stimulation of annual ephemerals may accentuate the competition for light and space and hinder perennial species development or harm their recruitment (Berger *et al.*, 2003; Kraufvelin *et al.*, 2007). Nutrient enrichment can also enhance fouling of *Fucus* fronds by biofilms (Olsenz, 2011). Nutrient enriched environments can not only increase algae abundance, but the abundance of grazing species (Kraufvelin, 2007). High nutrient levels may directly inhibit spore settlement and hinder the initial development of *Fucus vesiculosus* (Bergström *et al.*, 2003).

Kraufvelin *et al.* (2006) found only minor effects on the furoid community structure as a response to high nutrient levels during the first 3 years of an enrichment experiment. During the 4<sup>th</sup> year of exposure however, *Fucus serratus* started to decline and population consequently crashed in the 5<sup>th</sup> year. The study observed full recovery of algal canopy and animal community in less than 2 year after conditions returned to normal.

Changes in infralittoral community composition can happen rapidly, and fast growing ephemeral species can become established quickly in the presence of higher concentrations of nutrients. The establishment and growth of these species are not controlled by wave exposure (Kraufvelin, 2007). However, even though these fast growing ephemeral species can become well established quickly, healthy infralittoral communities can survive long periods of time, and maintain ecological function after these species have become established (Bokn *et al.*, 2002, 2003, Karez *et al.*, 2004, Kraufvelin, 2007, Kraufvelin *et al.*, 2006).

**Sensitivity assessment.** A slight increase in nutrients may enhance growth rates but high nutrient concentrations could lead to the overgrowth of the algae by ephemeral green algae and an increase in the number of grazers. If the biotope is well established and in a healthy state the biotope could persist. The extremely wave sheltered conditions and the weak to very weak water flows which are characteristic of this biotope mean that water mixing is not very strong. Lagoons are also known to have high levels of water retention rates which could exacerbate the negative impacts of this pressure. However, the biotope is 'Not Sensitive' at the pressure benchmark as the benchmark complies with all relevant environmental protection standards.

## Organic enrichment

High

Q: Medium A: Medium C: Medium

High

Q: High A: Medium C: Medium

Not sensitive

Q: Medium A: Medium C: Medium

The organic enrichment of a marine environment at this pressure benchmark leads to organisms no longer being limited by the availability of organic carbon. The consequent changes in ecosystem functions can lead to the progression of eutrophic symptoms (Bricker *et al.*, 2008), changes in

species diversity and evenness (Johnston & Roberts, 2009) and decreases in dissolved oxygen and uncharacteristic microalgae blooms (Bricker *et al.*, 1999, 2008).

Johnston & Roberts (2009) undertook a review and meta analysis of the effect of contaminants on species richness and evenness in the marine environment. Of the 49 papers reviewed relating to sewage as a contaminant, over 70% found that it had a negative impact on species diversity, <5% found increased diversity, and the remaining papers finding no detectable effect. None of the 49 papers considered the impact of sewage on lagoons. However, intertidal rocky shores were considered and are thought relevant to the characterizing species and to some of the features of the biotope. The findings are also still relevant as the meta analysis revealed that the effect of marine pollutants on species diversity were 'remarkably consistent' between habitats (Johnston & Roberts, 2009). It was found that any single pollutant reduced species richness by 30-50% within any of the marine habitats considered (Johnston & Roberts, 2009). Throughout their investigation there were only a few examples where species richness was increased due to the anthropogenic introduction of a contaminant. These examples were almost entirely from the introduction of nutrients, either from aquaculture or sewage outfalls. However, research into the impacts of organic enrichment from these sources on intertidal rocky shores often lead to shores lacking species diversity and the domination by algae with fast growth rates (Abou-Aisha *et al.*, 1995, Archambault *et al.*, 2001, Arévalo *et al.*, 2007, Diez *et al.*, 2003, Littler & Murray, 1975).

Major declines of *Fucus vesiculosus* have been reported from all over the Baltic Sea. These declines have been associated to eutrophication from nutrient enrichment (Kautsky *et al.*, 1986). Nutrient enrichment alters the selective environment by favouring fast growing, ephemeral species such as *Ulva lactuca* and *Ulva intestinalis* (Berger *et al.*, 2004, Kraufvelin, 2007). Rohde *et al.*, (2008) found that both free growing filamentous algae and epiphytic microalgae can increase in abundance with nutrient enrichment. This stimulation of annual ephemerals may accentuate the competition for light and space and hinder perennial species development or harm their recruitment (Berger *et al.*, 2003; Kraufvelin *et al.*, 2007). Nutrient enrichment can also enhance fouling of fucoid fronds by biofilms (Olsenz, 2011). Nutrient enriched environments can not only increase algae abundance, but the abundance of grazing species (Kraufvelin, 2007). High nutrient levels may directly inhibit spore settlement and hinder the initial development of *Fucus vesiculosus* (Bergström *et al.*, 2003). Bellgrove *et al.* (2010) found that coralline turfs out-competed fucoids at a site associated with organic enrichment caused by an ocean sewage outfall.

Changes in community composition on infralittoral shores can happen rapidly, and fast growing ephemeral species can become established quickly in the presence of higher concentrations of nutrients. The establishment and growth of these species are not controlled by wave exposure (Kraufvelin, 2007). However, even though these fast growing ephemeral species can become well established quickly, healthy infralittoral communities can survive long periods of time, and maintain ecological function after these species have become established (Bokn *et al.*, 2002, 2003, Karez *et al.*, 2004, Kraufvelin, 2007, Kraufvelin *et al.*, 2006b).

**Sensitivity assessment.** Little empirical evidence was found to support an assessment of this biotope at this benchmark. Due to the negative impacts that can be experienced with the introduction of excess organic carbon both resistance and resilience have been assessed as 'Medium'. This gives an overall sensitivity score of 'Medium'.

## **A** Physical Pressures

Resistance

Resilience

Sensitivity

**Physical loss (to land or freshwater habitat)****None**

Q: High A: High C: High

**Very Low**

Q: High A: High C: High

**High**

Q: High A: High C: High

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

**Physical change (to another seabed type)****None**

Q: High A: High C: High

**Very Low**

Q: High A: High C: High

**High**

Q: High A: High C: High

This biotope is characterized by a lagoon formed from bedrock, boulders and cobbles. Removal of this substratum would remove the attachment surface for the macroalgae that characterize this biotope, significantly altering the character of the biotope. Artificial hard substratum may also differ in character from natural hard substratum, so that replacement of natural surfaces with artificial may lead to changes in the biotope through changes in species composition, richness and diversity (Green *et al.*, 2012; Firth *et al.*, 2014) or the presence of non-native species (Bulleri & Airoldi, 2005).

**Sensitivity assessment.** A change to a sedimentary habitat would reduce habitat suitability for this biotope, resistance is assessed as 'None' and resilience as 'Very Low' as the change is considered to be permanent. Sensitivity is 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 for bedrock biotopes.

**Habitat structure changes - removal of substratum (extraction)****Not relevant (NR)**

Q: NR A: NR C: NR

**Not relevant (NR)**

Q: NR A: NR C: NR

**Not relevant (NR)**

Q: NR A: NR C: NR

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

**Abrasion/disturbance of the surface of the substratum or seabed****Low**

Q: High A: Medium C: Medium

**High**

Q: High A: Medium C: Medium

**Low**

Q: High A: Medium C: Medium

No studies of the effects of trampling or netting on lagoons were found but studies of the effects on emergent algal communities are probably indicative. Trampling on the rocky shore has been observed to reduce fucoid cover which decreased the microhabitat available for epiphytic species, increased bare space and increased cover of opportunistic species such as *Ulva* (Fletcher & Frid, 1996a). The location of this biotope within a saline lagoon means that the area is easily accessible by humans especially at low tide. Individual microalgae are flexible but not physically robust.

Furoids are intolerant of abrasion from human trampling, which has been shown to reduce the cover of seaweeds on a shore (Holt *et al.*, 1997).

Brosnan (1993) suggested that the presence or absence of foliose algae (e.g. furoids) could be used to indicate the level of trampling on the rocky shores of Oregon. In the UK, Boalch *et al.* (1974) and Boalch & Jephson (1981) noted a reduction in the cover of furoids at Wembury, south Devon, when compared to surveys conducted by Colman (1933). The size ranges of *Ascophyllum nodosum*, *Fucus vesiculosus* and *Fucus serratus* were skewed to a smaller length, and the abundance of *Ascophyllum nodosum*, in particular, was reduced (Boalch & Jephson, 1981). It was suggested that visitor pressure, especially after the construction of a car park, was responsible for the reduced cover of furoids (Boalch *et al.*, 1974). They suggested that the raised edges of the slatey rock, severed fronds when the rocks were walked over. However, no quantitative data was provided. Conversely, algal turfs seem to be relatively tolerant of the direct effects of trampling (based on the available evidence) and some species may benefit from the removal of canopy-forming algae (Tyler-Walters, 2005). Their tolerance may result from their growth form as has been shown for vascular plants and corals (Liddle, 1997). Brosnan (1993) suggested that algal turf dominated areas (on shores usually dominated by furoids) were indicative of trampling on the rocky shores of Oregon. However, tolerance is likely to vary with species and their growth form and little species specific data was found. Furthermore, algal turfs may suffer negative indirect effects where they form an understory below canopy forming species.

Pinn & Rodgers (2005) compared a heavily visited ledge with a less visited ledge at Kimmeridge Bay, Dorset. Although the mean species richness was similar at both sites, the total number of species was greater at the less utilized site. Comparatively, the heavily utilized ledge displayed a reduction in larger, branching algal species (e.g. *Fucus serratus*) and increased abundances of ephemeral and crustose species (e.g. *Ulva linza* and *Lithothamnium* spp. respectively). Fletcher and Frid (1996a; 1996b) examined the effects of persistent trampling on two sites on the north-east coast of England. The trampling treatments used were 0, 20, 80, and 160 steps per m<sup>2</sup> per spring tide for 8 months between March and November. Using multivariate analysis, they noted that changes in the community dominated by furoids (*Fucus vesiculosus*, *Fucus spiralis* and *Fucus serratus*) could be detected within 1 to 4 months of trampling, depending on intensity. Intensive trampling (160 steps/m<sup>2</sup> /spring tide) resulted in a decrease in species richness at one site. The area of bare substratum also increased within the first two months of trampling but declined afterwards, although bare space was consistently most abundant in plots subject to the greatest trampling (Fletcher & Frid, 1996a, 1996b). The abundance of furoids was consistently lower in trampled plots than in untrampled plots.

Fletcher & Frid (1996a; 1996b) also reported a decrease in the understory algal community of encrusting coralline algae and red algae, which was probably an indirect effect due to increased desiccation after removal of the normally protective furoid canopy (see Hawkins & Harkin, 1985) by trampling. They also noted that opportunistic algae (e.g. *Ulva* sp.) increased in abundance. Fletcher and Frid (1996a) report that the species composition of the algal community was changed by as little as 20 steps per m<sup>2</sup> per spring tide of continuous trampling since recolonization could not occur. A trampling intensity of 20 steps per m<sup>2</sup> per spring tide could be exceeded by only five visitors taking the same route out and back again across the rocky shore in each spring tide. Both of the sites studied receive hundreds of visitors per year and damage is generally visible as existing pathways, which are sustained by continuous use (Fletcher & Frid, 1996a, 1996b). However, the impact was greatest at the site with the lower original abundance of furoids.

Brosnan & Crumrine (1994) noted that trampling significantly reduced algal cover within 1 month

of trampling. Foliose algae were particularly affected and decreased in cover from 75% to 9.1% in trampled plots. *Mastocarpus papillatus* decreased in abundance from 9% to 1% in trampled plots but increased in control plots. *Fucus distichus* decreased in the summer months only to recover in winter but in trampled plots remained in low abundance (between 1 and 3% cover). Trampling resulted in a decrease in the cover of *Pelvetiopsis limitata* from 16% to 1.5%. *Iridaea cornucopiae* decreased from 38 to 14% cover within a month and continued to decline to 4-8% cover. However, after trampling ceased, recovery of algal cover including *Iridaea cornucopiae* and *Mastocarpus papillatus* was rapid (ca 12 months) (Brosnan & Crumrine, 1994). Schiel & Taylor (1999) also observed a decrease in understory algae (erect and encrusting corallines) after 25 or more tramples, probably due to an indirect effect of increased desiccation as above. However, Schiel & Taylor (1999) did not detect any variation in other algal species due to trampling effects. Similarly, Keough & Quinn (1998) did not detect any effect of trampling on algal turf species. In general, studies show that turf-forming algae appear to be relatively resistant to single events and low levels of trampling. Brosnan & Crumrine (1994), for example, found that in experimentally trampled plots the cover of foliose and canopy forming species declined while turf-forming algae were relatively resistant.

Schiel & Taylor (1999) reported the death of encrusting corallines one month after trampling, due to the removal of their protective canopy of fucoids by trampling (10 -200 tramples where one trample equals one transect walked by one person). A higher proportion of corallines died back in spring treatments, presumably due to the higher levels of desiccation stress expected at this time of year. However, encrusting corallines increased within the following year and cover returned to control levels within 21 months (Schiel & Taylor, 1999). Mechanical abrasion from scuba divers was also reported to impact encrusting corallines, with cover of *Lithophyllum stictaeforme* greater in areas where diving was forbidden than visited areas (abundance, 6.36 vs 1.4; it is presumed this refers to proportion of cover, although this is not clear from the text, Guarinieri *et al.*, 2012).

Dethier (1994) experimentally manipulated surface abrasion on a range of encrusting algae including *Lithophyllum impressum*. Crusts were brushed with either a nylon or steel brush for 1 minute a month for 24 months. Unbrushed controls grew by approximately 50% where the cover of nylon brushed crusts and steel brushed crusts decreased by approximately 25% and 40% respectively (interpreted from figures in Dethier, 1994). In laboratory tests on chips of *Lithophyllum impressum* brushing with a steel brush for 1 minute once a week for 3 weeks, resulted in no cover loss of two samples while a third 'thinned and declined' (Dethier, 1994).

**Sensitivity assessment.** The impact of surface abrasion will depend on the footprint, duration and magnitude of the pressure. Lagoons form natural shallow water mesocosms and can attract considerable attention from the general public, educational events and scientists alike. All of whom can cause abrasion damage to the species within the biotope. Abrasion of the substratum will cause a reduction in the abundances of both characterizing species, as well as other species found in the associated community. The resistance to this pressure at the benchmark level is 'Low'. The resilience is 'High' due to the fast recolonization abilities of the characterizing and associated species, giving a sensitivity of 'Low'.

**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 on hard rock,

which is resistant to subsurface penetration. Therefore, 'penetration' is '**Not relevant**'. The assessment for abrasion at the surface only is, therefore, considered to equally represent sensitivity to this pressure'. Please refer to 'abrasion' above.

### Changes in suspended solids (water clarity)

**Medium**

Q: High A: Medium C: Medium

**High**

Q: High A: Medium C: Medium

**Low**

Q: High A: Medium C: Medium

Light is an essential resource for all photoautotrophic organisms. A change in turbidity would affect light availability to photosynthesising organisms during immersion. This could lower both the growth rate and the biomass of photosynthetic organisms. Changes in the suspended sediment load could also change the levels of scour within the biotope. Those species which are not tolerant to an increase in scour would consequently decrease in abundance. Alternatively, if there was a decrease in the level of scour, competition may increase for the scour tolerant species as new species settle within the biotope. Due to the weak to very weak water flows and extremely wave sheltered position of this biotope, scour is not considered to have an important effect.

The distribution of *Fucus vesiculosus* occurs along a depth gradient which strongly correlates with light penetration. In areas with low sedimentation *Fucus vesiculosus* can survive down to 9-10 m depth (Eriksson & Bergstrom, 2005). Changes in suspended solids affecting water clarity will have a direct impact on the photosynthesising capabilities of *Fucus vesiculosus*. Irradiance below light compensation point of photosynthetic species can compromise carbon accumulation (Middelboe *et al.*, 2006). Kõuts *et al.* (2006) found decreases in light intensity in the vicinity of the dredging site resulted in the net decline of *Fucus vesiculosus* biomass. A decrease in light penetration in the Kiel Fjord caused by an increase in phytoplankton density and shading from filamentous algae has caused an upwards shift of the lower depth limit of *Fucus vesiculosus* (Rohde *et al.*, 2008).

**Sensitivity assessment.** The environmental conditions of this biotope mean that the biotope remains fully immersed throughout the tidal cycle. Therefore, a change in the pressure benchmark will have more effect on the *Fucus vesiculosus* and *Fucus serratus* within this biotope compared the effect that the pressure might have on them within an intertidal biotope. The lack of tidal effect will mean that the algae, especially those at the bottom limit of the biotope may become light limited. This may affect their growth rates and could potentially cause mortality of characterizing species, causing a decrease in the width of the biotope. The levels of water movement within this biotope, through water flow and wave exposure, are very unlikely to cause any significant damage through scour. Consequently, the resistance has been assessed as 'Medium' and resilience of this biotope has been assessed as 'High'. The sensitivity of this biotope to this pressure at the benchmark is 'Low'.

### Smothering and siltation rate changes (light)

**Low**

Q: High A: Medium C: Medium

**Medium**

Q: High A: Medium C: Medium

**Medium**

Q: High A: Medium C: Medium

A discrete event where 5 cm of sediment is deposited into the lagoon will partially cover the stipe and holdfast of the characterizing species. Leaving the fronds sediment free, and able to continue photosynthesising. The low water flow and wave sheltered position on this biotope will mean that the sediment will not be removed from the shore quickly.

Germlings are likely to be smothered and killed by this pressure. Indeed early life stages are smaller in size than adults and are thus most vulnerable to this pressure as even a small load of added sediment will lead to the complete burial. Sediment deposition can reduce macroalgal

recruitment by (1) reducing the amount of substratum available for attachment of propagules; (2) scour, removing attached juveniles and (3) burial, altering the light and/or the chemical microenvironment (Devlinny & Vorse, 1978, Eriksson & Johansson, 2003). Berger *et al.* (2003) demonstrated that both interference with sediment during settlement, and burial after attachment, were significant causes of mortality for *Fucus vesiculosus* germlings. Eriksson & Johansson (2003) found that sedimentation had a significant negative effect on the recruitment success of *Fucus vesiculosus*. Even fine sediment fractions can reduce the successful attachment of fucoids by as much as 90% (Schiel & Foster, 2006).

Another consideration for this biotope is the effect that sedimentation may have on the physical aspect of the lagoon. If saline lagoons become silted up then the basin can be raised above percolation input, causing the lagoon to become a freshwater lake (Bamber *et al.*, 2001). Each lagoon will respond differently to 5 cm of sediment inundation and there is no evidence to suggest how different lagoons might respond.

**Sensitivity assessment.** *Fucus vesiculosus* adults are relatively tolerant to sediment inundation and can regenerate from its holdfast. Germlings of both *Fucus vesiculosus* and *Fucus serratus* are intolerant of even small levels of sediment. Many of the smaller species found within the associated community will be totally smothered by 5 cm. This biotope is found in extremely wave sheltered conditions. Therefore, sediment is likely to be retained for long periods of time, allowing greater negative effects to occur. Resistance has been assessed as 'Low' and resilience is assessed as 'Medium'. Overall the biotope probably has a 'Medium' sensitivity to smothering at the level of the benchmark.

#### Smothering and siltation rate changes (heavy)

**Low**

Q: High A: Medium C: Medium

**Medium**

Q: High A: Medium C: Medium

**Medium**

Q: High A: Medium C: Medium

A deposit at the pressure benchmark would cover all species with a thick layer of fine materials. Species associated with this biotope such as limpets and littorinids would not be able to escape and would likely suffer mortality (see evidence for light siltation). The low water flow and wave sheltered position on this biotope will mean that the sediment will not be removed from the shore quickly. Therefore, sediment is likely to be retained for long periods of time, allowing greater negative effects to occur. Resistance has been assessed as 'Low' and resilience is assessed as 'Medium'. Overall the biotope probably has a 'Medium' sensitivity to smothering at the level of the benchmark. The biotope could be more sensitive to this pressure however, there is insufficient evidence to create a more detailed assessment.

#### 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

**Not relevant (NR)**

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

Species characterizing this habitat do not have hearing perception but vibrations may cause an impact, however no studies exist to support an assessment.

**Introduction of light or shading**

No evidence (NEv)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

Increased levels of diffuse irradiation correlate with increased growth in macroalgae (Aguilera *et al.*, 1999). Macroalgae require light to photosynthesize so that changes in light intensity are likely to affect photosynthesis, growth, competition and survival. Chapman (1995) noted that too little or too much light are likely to be stresses. Levels of diffuse irradiation increase in summer, and with a decrease in latitude. As *Fucus vesiculosus* and *Fucus serratus* are found in the middle their natural range in the British Isles an increase in the level of diffuse irradiation will not cause a negative impact on the species or the biotope. However, it is not clear how these findings may reflect changes in light levels from artificial sources, and whether observable changes would occur at the population level as a result. There is, therefore, 'No evidence' on which to base an assessment.

**Barrier to species movement**

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

This pressure is considered applicable to mobile species, e.g. fish and marine mammals rather than seabed habitats. Physical and hydrographic barriers may limit propagule dispersal. But propagule dispersal is not considered under the pressure definition and benchmark. Therefore this pressure is considered 'Not Relevant' for this biotope.

**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**

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

Key characterizing species within this biotope are not cultivated or translocated. This pressure is therefore considered not relevant to this biotope.

### Introduction or spread of invasive non-indigenous species

No evidence (NEv)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

Thompson & Schiel (2012) found that native furoids show high resistance to invasions by the Japanese kelp *Undaria pinnatifida*. However, cover of *Fucus vesiculosus* was inversely correlated with the cover of the invasive *Sargassum muticum* indicating competitive interaction between the two species (Stæhr *et al.*, 2000). Stæhr *et al.* (2000) determined that the invasion of *Sargassum muticum* could affect local algal communities through competition mainly for light and space.

*Gracilaria vermiculophylla* is suggested to be one of the most successful marine non-native species (Kim *et al.*, 2010, Sfriso *et al.*, 2010 taken from Thomsen *et al.*, 2013). This species invades wave sheltered, shallow water areas, and have been found in biotopes naturally dominated by furoid canopies (Weinberger *et al.*, 2008). Hammann *et al.* (2013) found that in the Baltic Sea *Gracilaria vermiculophylla* could impact *Fucus vesiculosus* through direct competition for resources, decreasing the half-life of germlings, and increasing the level of grazing pressure. To date *Gracilaria vermiculophylla* has only been recorded in Northern Ireland. The introduction of this species to infralittoral shores around the British Isles could have negative impacts on native furoid biotopes, and could become relevant to this specific biotope.

**Sensitivity assessment.** Furoid species have been negatively affected by both the direct and indirect consequences of INNS being present. However, no evidence can be found on the impacts of INNS on *Fucus vesiculosus* and *Fucus serratus* within this biotope. For this reason the effect of this pressure has been given as 'No Evidence'. Literature for this pressure should be revisited.

### Introduction of microbial pathogens

No evidence (NEv)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

Very little is known about infections in *Fucus* (Wahl *et al.*, 2011). Coles (1958) identified parasitic nematodes that caused galls on *Fucus serratus* in the Southwest of Britain. But to date no mortalities have been associated to the introduction of microbial pathogens. Torchin *et al.* (2002) suggests that there is potential for increased biotic interactions with parasites or pathogens in many marine systems. More recently, Zuccaro *et al.* (2008) detected a number of fungal species associated with *Fucus serratus*. So far no mortalities have been associated to the introduction of microbial pathogens. However, the potential for increased biotic interactions involving parasites or pathogens is on the rise in many marine systems (Torchin *et al.*, 2002). No evidence was found for pathogens of red algae which may be present in this biotope. Other species associated with this biotope such as littorinids experience low levels of infestation by pathogens but mass-mortalities have not been recorded. For example, parasitism by trematodes may cause sterility in *Littorina littorea*. *Littorina littorea* are also parasitized by the boring polychaete, *Polydora ciliate* and *Cliona sp*, which weakens the shell and increases crab predation. An assessment of 'No Evidence' has been given for this biotope due to the lack of direct evidence.

### Removal of target species

Low

Q: High A: Medium C: Medium

High

Q: High A: Medium C: Medium

Low

Q: High A: Medium C: Medium

Seaweeds have been collected from the middle of the 16th century for the iodine industry. Modern day industrial uses for seaweed are extensive and include fertilizer, animal feed, alginate extracts (Phillipi *et al.*, 2014), water treatment, and human food and health supplements (Bixler & Porse, 2010). *The characteristic fucoid algae within this biotope are commercially collected.* These commercial harvests remove seaweed canopies which have important effects on the wider ecosystem.

Stagnol *et al.* (2013) investigated the effects of commercial harvesting of intertidal fucoids on ecosystem biodiversity and functioning. The study found that the removal of the macroalgae canopy affected the metabolic flux of the area. Flows from primary production and community respiration were lower on the impacted area as the removal of the canopy caused changes in temperature and humidity conditions (Stagnol *et al.*, 2013).

Stagnol *et al.* (2013) found that suspension feeders were the most affected by the canopy removal as canopy-forming algae are crucial habitats for these species. Other studies confirm that loss of canopy had both short and long-term consequences for benthic community diversity resulting in shifts in community composition and a loss of ecosystem functioning such as primary productivity (Lilley & Schiel, 2006; Gollety *et al.*, 2008).

Red algae within the biotope may also be subject to hand gathering. *Mastocarpus stellatus* is harvested commercially in Scotland and Ireland to produce carageen, the stipe is removed but the base is left intact to allow the algae to re-grow. *Palmaria palmata* and *Osmundea pinnatifida* are also collected by hand commercially and recreationally for consumption.

Littorinids are one of the most commonly harvested species of the rocky shore. Large scale removal of *Littorina littorea* may allow a proliferation of opportunistic green algae, such as *Ulva*, on which it preferentially feeds. Experiments designed to test the effects of harvesting by removing individuals at Strangford Lough found that there was no effect of experimental treatments (either harvesting or simulated disturbance) on *Littorina littorea* abundance or body size over a 12 week period (Crossthwaite *et al.*, 2012). This suggests that these animals are generally abundant and highly mobile; thus, animals that were removed were quickly replaced by dispersal from surrounding, un-harvested areas. However, long-term exploitation, as inferred by background levels of harvest intensity, did significantly influence population abundance and age structure (Crossthwaite *et al.*, 2012). A broadscale study of harvesting in Ireland using field studies and interviews with wholesalers and pickers did suggest that some areas were over harvested. But the lack of background data and quantitative records make this assertion difficult to test (Cummins *et al.*, 2002). Changes in grazer abundance can alter the character of the algal assemblage. Grazer removal (manual removal of all gastropods in pool and a 1 m surrounding perimeter) caused strong and highly significant changes in assemblage structure in rockpools that contained red turf forming algae mainly due to an increase in the cover of green filamentous algae and a decrease in cover of live crustose coralline algae (25.40%) (Atalah & Crowe, 2010).

**Sensitivity assessment.** The removal of *Fucus vesiculosus* and *Fucus serratus* canopy will significantly change the community composition of the biotope. The quantity of biomass removed from the shore and the regularity of removal will all affect how quickly the biotope will be able to recover. *Fucus vesiculosus* and *Fucus serratus* have a 'Low' resistance to removal as both of them are easy to locate and have no escape strategy. Resilience is 'High', however recovery will only be able to start when the pressure is removed from the shore i.e. harvesting is no longer occurring. A sensitivity of 'Low' is recorded.

## Removal of non-target species

**Low**

Q: Medium A: Medium C: Medium

**High**

Q: High A: Medium C: Medium

**Low**

Q: Medium A: Medium C: Medium

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The characterizing species *Fucus vesiculosus* and *Fucus serratus* are the dominant species within this biotope. The dominance of these characterizing species means it could easily be incidentally removed from this biotope as by-catch when other species are being targeted. The loss of this species and other associated species would decrease species richness and negatively impact on the ecosystem function.

**Sensitivity assessment.** Removal of a large percentage of the characterizing species would alter the character of the biotope. The resistance to removal is 'Low' due to the easy accessibility of the biotopes location and the inability of these species to evade collection. The resilience is 'Medium', with recovery only being able to begin when the harvesting pressure is removed altogether. This gives an overall sensitivity score of 'Medium'.

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