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Marine Information Network

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

Fucus serratus with sponges, ascidians and red seaweeds on tide-swept lower eulittoral mixed substrata

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

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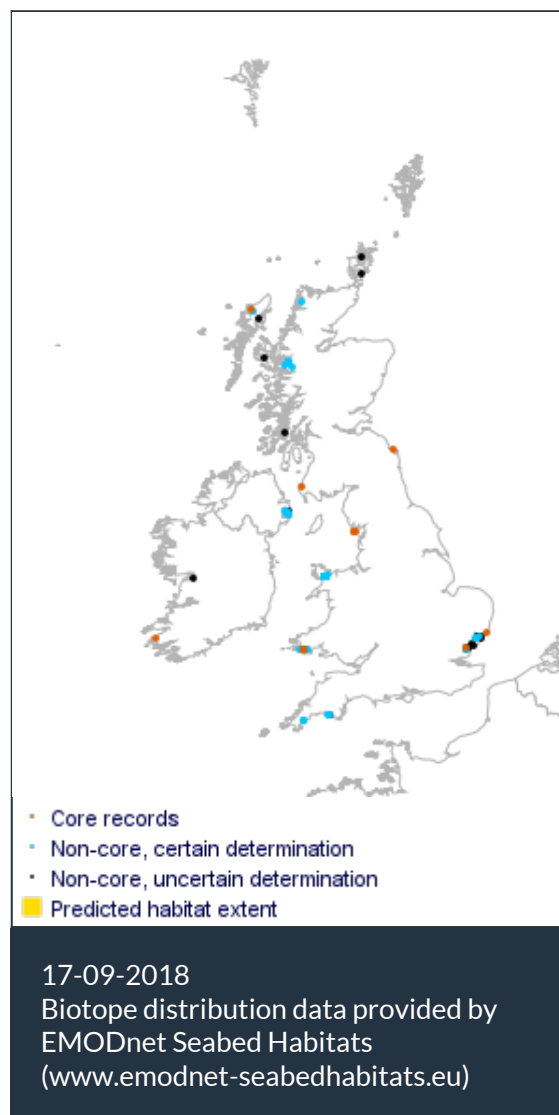
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Researched by Emelia d'Avack and Charlotte Marshall

Refereed by This information is not refereed.

Summary

☰ UK and Ireland classification

EUNIS 2008	A1.153	<i>Fucus serratus</i> with sponges, ascidians and red seaweeds on tide-swept lower eulittoral mixed substrata
JNCC 2015	LR.HLR.FT.FserTX	<i>Fucus serratus</i> with sponges, ascidians and red seaweeds on tide-swept lower eulittoral mixed substrata
JNCC 2004	LR.HLR.FT.FserTX	<i>Fucus serratus</i> with sponges, ascidians and red seaweeds on tide-swept lower eulittoral mixed substrata
1997 Biotope	LR.SLR.FX.FserX.T	<i>Fucus serratus</i> with sponges, ascidians and red seaweeds on tide-swept lower eulittoral mixed substrata

🔍 Description

Sheltered lower shore boulders, cobbles and pebbles on muddy sediments that are subject to enhanced tidal water movement may be characterized by a rich community of sponges

(*Halichondria panicea* and *Hymeniacion perleve*), hydroids (*Dynamena pumila*), bryozoans (*Anguinella palmata* and *Walkeria uva*), ascidians (*Asciella aspersa*, *Asciella scabra*, *Styela clava* and *Botryllus schlosseri*) and red seaweed (*Halurus flosculosus*, *Ceramium* sp., *Gracilaria verrucosa* and *Chondrus crispus*). The brown algae *Dictyota dichotoma*, *Fucus serratus* and *Ectocarpus* sp. may be found on any more stable substrata. Patches of sand or mud are often characterized by the sand mason worm *Lanice conchilega*, the peacock worm *Sabella pavonina* and the anemone *Sagartia troglodytes*. Aggregations of the mussel *Mytilus edulis* and, in southern and eastern England, the slipper limpet *Crepidula fornicata* may also be found attached to cobbles and pebbles. Sites in Scottish sealochs may support maerl *Lithothamnion corallioides* and bivalves *Venerupis senegalensis* (see also IMX.VsenMtru). (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

↓ Depth range

Lower shore

🏛️ Additional information

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✓ Listed By

- none -

🔗 Further information sources

Search on:



Habitat review

🔄 Ecology

Ecological and functional relationships

- Due to the moderately strong currents associated with this biotope, suspension feeders are the dominant trophic group, indicating the importance of a planktonic input to the benthic community. Suspension feeders frequently associated with this biotope represent four phyla: the sponges *Halichondria panicea* and *Hymeniacion perleve*, ascidians such as *Asciidiella aspersa*, molluscs including the slipper limpet *Crepidula fornicata* and common mussel *Mytilus edulis* and crustaceans such as barnacle *Elminius modestus*.
- The sand mason *Lanice conchilega* (a polychaete worm) is primarily a deposit feeder, feeding preferentially on detritus. However, when *Lanice conchilega* occurs in high densities, competition at the sediment surface forces it to suspension feed (Buhr & Winter, 1977).
- The common periwinkle *Littorina littorea* is a herbivore and commonly feeds on fine brown, green and red algae. The chiton *Lepidochitona cinerea* also grazes on algae and micro organisms.
- The common shore crab *Carcinus maenas* is the largest mobile predator frequently associated with this biotope and is likely to move between the boulders and pebbles feeding primarily on small molluscs, especially *Littorina* sp. and *Mytilus edulis*, annelids and other crustacea. It is a true omnivore and will also consume algal material.
- Autotrophs in the biotope are varied and include representatives from the brown, green and red algal groups such as *Fucus serratus*, *Bryopsis plumosa* and *Chondrus crispus* respectively. The algae themselves may provide substratum for epiphytes including hydroids, sponges and ascidians. In addition, clumps of algae are likely to provide refuge for smaller crabs and periwinkles which may otherwise be washed away by the strong water flow.
- Due to the eulittoral position of this biotope, the associated fauna are likely to experience some predation from birds, when exposed at low tide and shallow water fish at high tides.

Seasonal and longer term change

The plants in this biotope are likely to experience some seasonal change in abundance, the general pattern being a lower percentage cover over the winter months. However, this biotope is limited to habitats that are sheltered to extremely sheltered from wave exposure and, therefore, increases in wave exposure during winter and the occurrence of winter storms are unlikely to affect it to the same extent that more exposed habitats would be affected. In some habitats, the surface cover of *Fucus serratus* may reach 95% in the summer months. Ephemeral green algae especially, increase in abundance over the summer months.

Any increase in wave exposure and storm frequency over the winter months is likely to result in the resuspension and subsequent redeposition of the mixed sediment substratum. If the forces were strong enough, the pebbles and boulders may also be moved around. Redistribution of the larger pebbles and boulders may be to the detriment of the epilithic fauna. For example, if colonies of sponges and ascidians on the rock landed face down into the sediment, their feeding would be interrupted and that part of the colony would die. In the Bay of Fundy, Canada, the abundance of the hydroid *Dynamena pumila* declined dramatically over the winter months as a result of ice scour (Henry, 2002) which is likely to have a similar effect to the scour of the mixed sediment in this

biotope. Similarly, if plants were trapped under the boulders they may also die unless subsequent movement of the boulders released them. Periodic storms may remove older and weaker plants and reduce the overall biomass of the plants.

Habitat structure and complexity

The substratum within this biotope is mixed and structurally complex, offering a wide variety of potential habitats including boulders, cobbles, pebbles and muddy sediments. This means that there will be a mix of both infauna, epifauna and epilithic species. In addition, *Fucus serratus* and red seaweeds offer a substratum for colonization by epiflora including bryozoans and sponges. 91 taxa of associated fauna were found on 65 specimens of *Fucus serratus* in Strangford Lough, Northern Ireland (Boaden *et al.*, 1975). Clumps of seaweed also offer refuge for *Carcinus maenas* and the grazer *Littorina littorea*. Small patches of the mussel *Mytilus edulis* may provide refuge for a diverse range of small invertebrates including polychaetes and *Littorina* sp.. The empty shells of the molluscs also provide some heterogeneity to the substratum.

Productivity

Very little is known about the productivity of this biotope, or indeed of intertidal mixed sediment communities in general. However, the small patches of macroalgae associated with this biotope can exude dissolved organic carbon, which is 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. This may enter the food chain of local subtidal ecosystems, or be exported further offshore. Many of the species associated with this biotope make a contribution to the food of many marine species through the production of planktonic larvae and propagules, which contribute to pelagic food chains. There is likely to be less productivity than on fucoid dominated rocky shore such as MLR.MytFves and MLR.BF.

Recruitment processes

For the majority of important characterizing species and other important species within this biotope, reproduction and recruitment is an annual process. For some of the species, such as the common mussel *Mytilus edulis*, common shore crab *Carcinus maenas* and common periwinkle *Littorina littorea*, various stages in the reproductive process, including gametogenesis, the timing of spawning and/or recruitment, are variable depending on, for example, environmental factors and geographic location. Recruitment in the major groups present is summarized below.

- Reproduction in *Fucus serratus* commences in late spring and continues until November, with a peak in August and October. Eggs and sperm are produced separately and fertilized externally to form a planktonic zygote. Recruitment is therefore possible from sources outside the biotope.
- *Chondrus crispus* has an extended reproductive period (e.g. Pybus, 1977; Fernandez & Menendez, 1991; Scrosati *et al.*, 1994) and produces large numbers of spores (Fernandez & Menendez, 1991). Although growth of sporelings is not rapid in comparison to other macroalgae, maturity is probably reached approximately 2 years after initiation of the basal disc (Pybus, 1977). The spores of red algae are non-motile (Norton, 1992) and therefore entirely reliant on the hydrographic regime for dispersal. Hence, it is expected that *Chondrus crispus* would normally only recruit from local populations and that recovery of remote populations would be much more protracted.
- There is some debate as to the nature of reproduction in the breadcrumb sponge *Halichondria panicea* but it is likely that it has a short, annual season of reproduction (see

MarLIN review).

- The larvae of the sea squirt *Ascidiella aspersa* have a short free-swimming planktonic stage. However, time taken from fertilization until settlement and metamorphosis is only about 24 hours at 20 °C (Niermann-Kerkenberg & Hofmann, 1989) and, therefore, widespread dispersal seems unlikely.
- *Mytilus edulis* has a protracted spawning in many places and fecundity is affected by many factors (see MarLIN review). The planktonic life of larvae may exceed two months and, hence, there is a good chance of wide dispersal and recruitment from external sources. Due to the highly gregarious nature of *Mytilus edulis* settlement, persistent mussel beds can be maintained by relatively low levels of recruitment.
- The larvae of the sand mason *Lanice conchilega* can spend up to sixty days in the plankton therefore providing good potential for dispersal and recruitment from external sources.
- The duration of the breeding season in the common shore crab *Carcinus maenas* depends on the geographic location of the population. Females on the south coast of Britain can bear eggs all year round and fecundity is high (see MarLIN review).
- Fecundity in the common periwinkle *Littorina littorea* can reach 100,000 eggs in large females. The reproductive season is annual and episodic with a pelagic phase of up to six weeks. *Littorina littorea* can also breed all year, although the length and timing of the season depend on climate.
- Dispersal of the hydroid *Dynamena pumila* is restricted to the planula stage which usually settles and starts to metamorphose within 60 hours of release (Orlov, 1996). Orlov (1996) that long-distance dispersal was further restricted by the dense bushes of neighbouring algae which serve to trap the larvae in the area.

Time for community to reach maturity

No information was found concerning the development of this biotope. However, the important characterizing species all reach sexual maturity within three years and have annual reproductive episodes suggesting that the time taken for the community to develop is likely to be less than five years. However, if adverse environmental conditions prevail, time taken to reach maturity could take significantly longer.

Additional information

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Preferences & Distribution

Habitat preferences

Depth Range	Lower shore
Water clarity preferences	
Limiting Nutrients	Data deficient
Salinity preferences	Full (30-40 psu), Variable (18-40 psu)
Physiographic preferences	Enclosed coast / Embayment, Strait / sound
Biological zone preferences	Lower eulittoral
Substratum/habitat preferences	Large to very large boulders, Small boulders, Cobbles, Muddy sand, Muddy gravel

Tidal strength preferences	Moderately Strong 1 to 3 knots (0.5-1.5 m/sec.)
Wave exposure preferences	Extremely sheltered, Sheltered, Very sheltered
Other preferences	Moderately strong tidal streams

Additional Information

SLR.FserX.T occurs in sheltered to extremely sheltered habitats. Connor *et al.* (1997b) consider this biotope to be uncommon in Britain.

Species composition

Species found especially in this biotope

Rare or scarce species associated with this biotope

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Additional information

The MNCR recorded 423 species in 22 records of this biotope although not all of the species occurred in all records of the biotope (JNCC, 1999).

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

This biotope is characterized by the macroalgae *Fucus serratus* and a rich assemblage of filter-feeding fauna encouraged by moderately strong to very strong tidal currents. The filter feeding communities include the sponges *Halichondria panacea*, *Grantia compressa* and *Hymeniacion perleve* as well as the sea squirts *Ascidiella scabra* and *Dendrodia grossularia*. Underneath the *Fucus serratus* canopy is a diverse flora of foliose red seaweeds including *Chondrus crispus* and *Lomentaria articulata*. Other species such as the limpet *Patella vulgata* and the tube building worm *Spirobranchus triqueter* are also present.

Fucus serratus is the key structuring species as the macroalgae form a canopy within this biotope that provides protection from desiccation for the various underlying foliose red seaweeds in addition to providing a substratum for a diverse range of epifauna. Characterizing elements of this biotope are sponges, ascidians and red seaweeds in particular *Halichondria panacea*, *Ascidiella scabra* and *Chondrus crispus*. The sensitivity assessments consider the characterizing species that define this biotope; *Fucus serratus*, sponges and ascidians. Loss/degradation of the *Fucus serratus* population would thus result in direct loss/degradation of the associated community and significantly alter the character of the biotope. Therefore, the assessments typically emphasise the sensitivity of *Fucus serratus*.

Resilience and recovery rates of habitat

The loss of *Fucus serratus* canopy will have both short and long-term consequences for associated benthic communities, resulting in the loss of biogenic habitat, reduction in diversity, simplification of vertical structure and reduction or loss of ecosystem functioning such as primary productivity (Lilley & Schiel, 2006). The removal of macroalgae canopy exposes understory species to sunlight and aerial conditions during low tides resulting in bleaching and eventual die backs. Through time, some functional groups, such as low-lying turfing algae, recover and reach greater abundance compared to prior disturbance conditions (Bulleri *et al.*, 2002; Bertocci *et al.*, 2010). These turf algae can then prevent canopy recovery by inhibiting recruitment. Schiel & Foster (2006) observed long-term demographic lags in recovery after important losses of furoids. Recovery of lost or severely reduced species can be slow, with species replacement common. Indeed loss of furoids can cause systems shifts to a state dominated by low-lying turf or filamentous ephemeral algae (Airoldi *et al.*, 2008; Mangialajo *et al.*, 2008; Perkol-Finkel & Airoldi, 2010). Turf algae, especially corallines, are often highly resilient and positively associated with perturbed areas. The changes in dominant species and community structure take some time to develop and, although some effects occur rapidly, many are manifested over a period of several years (Schiel & Lilley, 2011). Hawkins & Southward (1992) found that, after the *Torrey Canyon* oil spill, it took between 10 and 15 years for the *Fucus* sp. to return to 'normal' levels of spatial and variation in cover on moderately exposed shores. Therefore, for factors that totally destroy the biotope, recovery is likely to be low.

Fucus serratus is dioecious, perennial and reproduces sexually. Reproduction commences in late spring/early summer and continues through summer and autumn, peaking in August - October. Eggs and sperm are released into the water and fertilization occurs in the water column. The zygote then develops into a minute plant that can then settle onto the substratum. 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* have been

estimated at 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 (Coyer *et al.*, 2006). *Fucus serratus* does not float, and thus mature detached individuals cannot transport reproductive material to distant sites as might be the case for other brown algae. 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).

Chondrus crispus has an extended reproductive period (e.g. Pybus, 1977; Fernandez & Menendez, 1991; Scrosati *et al.*, 1994) and produces large numbers of spores (Fernandez & Menendez, 1991). Recovery of a population of *Chondrus crispus* following a perturbation is likely to be largely dependent on whether holdfasts remain, from which new thalli can regenerate (Holt *et al.*, 1995). In addition, the spores of red algae are non-motile (Norton, 1992) and therefore entirely reliant on the hydrographic regime for dispersal. Hence, similar to *Fucus serratus*, *Chondrus crispus* would normally only recruit from local populations slowing down the recovery of remote populations. Minchinton *et al.* (1997) documented the recovery of *Chondrus crispus* after a rocky shore in Nova Scotia, Canada, was totally denuded by an ice scouring event. Initial recolonization was dominated by diatoms and ephemeral macroalgae, followed by furoids and then perennial red seaweeds. After 2 years, *Chondrus crispus* had re-established approximately 50% cover on the lower shore and after 5 years it was the dominant macroalga at this height, with approximately 100% cover. Minchinton *et al.* (1997) concluded that although *Chondrus crispus* was a poor colonizer, it was the best competitor.

The larvae of the sea squirt *Ascidella aspersa* have a short free-swimming planktonic stage. Fertilization to settlement and metamorphosis is estimated to only take about 24 hours at 20°C (Niermann-Kerkenberg & Hofmann, 1989). The congener *Ascidella scabra* has a high fecundity and settles readily, probably for an extended period from spring to autumn. Svane (1988) describes it as 'an annual ascidian' and demonstrated recruitment onto artificial and scraped natural substrata. It is also likely that *Ascidella scabra* larvae are attracted by existing populations and settle near to adults (Svane *et al.*, 1987). Fast growth means that a dense cover could be established within about 2 months. However, if mortality occurs at a time when larvae are not being produced, other species may settle and dominate in the freed spaces.

The settlement of new colonies of the breadcrumb sponge *Halichondria panicea* is likely to occur within one year with growth rate ranging from 0.1 to 0.4 cm²/day. Knowlton & Highsmith (2005) found a rapid response to tissue damage from nudibranch grazing with the sponge recovering within 4 weeks from grazing impacts.

Resilience assessment. *Fucus serratus* is the main structural species as its removal will lead cause the decline of associated species and eventually to a change towards a different biotope. If the entire population of *Fucus serratus* is lost other species may come to dominate. Where resistance is 'None', then resilience is 'Low' based on the low long-distance dispersal range of *Fucus serratus*. Re-establishment of the seaweed may depend on the ability to out-compete other species and this may be dependent on suitable environmental conditions. Upon arrival, the success of the new population is explained by: (1) rapid establishment of monospecific patches in the immediate vicinity of the founding plants, (2) high colonization rates of disturbed areas, (3) the ability to recruit to undisturbed canopies, (4) the ability to outgrow resident canopy species (particularly *Fucus vesiculosus*) and (5) the increase in size and number of dispersal centres (Arrontes, 2002).

If some of the population remains it is unlikely that other species will come to dominate due to efficient recruitment of *Fucus serratus* over short distance. Removal of some of the adult canopy will allow the understorey germling to grow faster. Recovery will probably have occurred after a year. Therefore when resistance is 'Medium', recovery will be very fast resulting in a 'High' resilience score due to very efficient colonization of areas adjacent to *Fucus serratus* patches. If resistance is assessed as 'High', resilience is automatically 'High' as there are not impacts to recover from.

Strong tidal currents, characteristic of this biotope, encourage communities of sponges and ascidians. Changes to the hydrological regime are therefore likely to directly influence the presence of these species. Once removed, these species are however likely to rapidly recolonize due to planktonic larvae thereby facilitating recruitment. Most species associated with this biotope are poor long distance dispersers. However the moderately strong tidal currents of this biotope enable these species to disperse over greater distances than in slow flowing environments.

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

Hydrological Pressures

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

Most fucoids are cold-temperate species (Lüning, 1984), and temperatures above 20°C are generally considered unsuitable (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). However, *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.

Increased temperature (>15°C) can enhance biotic stress on *Fucus* plants by increasing micro- and macrofouling rates (Wahl *et al.*, 2010). Several studies observed adverse effects of *Fucus serratus* as a result to 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) however determined that these negative impacts can be explained by within-population genetic diversity. Southwest-Ireland and Brittany are hot-spots of genetic diversity (Coyer *et al.*, 2003; Hoarau *et al.*, 2007) and may thus be more resilient to changes in temperature. Indeed, Nielsen *et al.* (2014) found no negative effects on growth rates of adult *Fucus*

serratus to water temperatures of 22°C (laboratory experiment with specimen collected from Firth of Forth, Scotland). Phenotypic plasticity plays therefore an important role in determining the sensitivity of individual populations to changes in temperature.

The geographical ranges of a variety of associated species such as *Halichondria panicea*, *Chondrus crispus* and *Ascidiella scabra* suggest that these organisms will be tolerant to a change in temperature at the pressure benchmark. It is however possible that acute changes in temperature will have adverse effects resulting in mortalities.

Sensitivity assessment. An increase in 5°C above average British and Irish temperatures is not likely to have a detrimental effect of *Fucus serratus* and associated communities, however, phenotypic plasticity will influence the tolerance of individual population. Resistance and resilience are therefore both assessed as 'High' (no impacts to recover from). The biotope group is 'Not Sensitive' to a change in temperature at the pressure benchmark.

Temperature decrease (local)

High

Q: High A: Low C: NR

High

Q: High A: High C: High

Not sensitive

Q: High A: Low C: Low

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. The seaweed is thus well within its thermal range in the British Isles. Lüning (1984) placed this species in his 'Cold temperature North Atlantic group'.

Sensitivity assessment. A decrease in acute or chronic temperature above average British and Irish temperatures is not likely to have a detrimental effect of *Fucus serratus* and associated communities, based on global distribution. However, it should be noted that phenotypic plasticity will influence the tolerance of individual population. Resistance and resilience are therefore both assessed as 'High' (no impacts to recover from). The biotope group is 'Not Sensitive' to a change in temperature at the pressure benchmark.

Salinity increase (local)

Medium

Q: Low A: NR C: NR

High

Q: High A: High C: Medium

Low

Q: Low A: NR C: NR

This biotope group is found in the intertidal and is therefore likely to experience cyclical periods of hypo- and hyper-salinity. Seaweeds 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).

Sensitivity assessment. *Fucus serratus*, commonly inhabit narrow fjords where salinity can vary widely along a spatial (kms) and/or temporal (hours to daily) scale. Species associated with this biotope are therefore likely to be tolerant to an increase in salinity from 35 to 40 units for one year. No direct evidence was found on the effects of hypersaline (>40 units) conditions. However, hypersaline conditions may result in damage to the furoid but loss of associated community (e.g. ascidians and sponges). Therefore a tentative resistance of 'Medium' is recorded, at low confidence. Resilience is probably 'High', so that the biotope is probably of 'Low' sensitivity at the pressure benchmark.

Salinity decrease (local)**High**

Q: High A: High C: High

High

Q: High A: High C: Medium

Not sensitive

Q: High A: High C: Medium

This biotope group is found in the intertidal and is therefore likely to experience cyclical periods of hypo- and hyper-salinity. Seaweeds 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, 1992; 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 fertilization success was 87% at 9 psu but declined to 5% at 6 psu. Reduced salinity also affects dispersal by decreasing swimming performance of furoid sperm (Serrão *et al.*, 1996).

Other characterizing species associated with this biotope are likely to be tolerant of a reduction in salinity. *Halichondria panacea*, *Chondrus crispus* and *Asciidiella scabra* can all be found in reduced salinity conditions. *Patella vulgata* can endure periods of low salinity and was found to die only when the salinity was reduced to 3-1 psu (Fretter & Graham, 1994). However, Little *et al.* (1991) observed reduced levels of activity in limpets after heavy rainfall and in the laboratory activity completely stopped at 12 psu.

Sensitivity assessment. At the level benchmark a reduction in salinity of from full to variable or reduced in one year could have beneficial effects on *Fucus serratus* as growth rates are maximal below full saline conditions. Other characterizing species associated with this biotope are also tolerant of reduced salinity at the level of the benchmark. Resistance and resilience are therefore both assessed as 'High' (no impacts to recover from). The biotope is therefore 'Not Sensitive'.

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

Q: High A: Low C: Medium

High

Q: High A: High C: High

Not sensitive

Q: High A: Low C: Medium

The rich community of suspension feeders in this biotope is, in part, due to the strong tidal streams with which it is associated. Strong currents provide suspension feeder with a continual supply of food and removes sediment that would otherwise interfere with their feeding apparatus. A decrease in water flow rate could lead to siltation, to the detriment of filter feeders. Furthermore, grazers unable to cope with the strong flow rates normally associated with this biotope may be able to graze more efficiently, increasing herbivory pressure. High water flow rates increases mechanical stress on macroalgae by increasing drag. This can result in individuals being torn off the substratum. Once removed, the attachment cannot be reformed causing the death of the algae. Any sessile organisms attached to the algae are also lost. Furoids are however highly flexible and are able to reorientate their position in the water column to become more streamlined. By going with the flow, furoids can reduce the relative velocity between algae and the surrounding water, thereby reducing drag and lift (Denny *et al.*, 1998). Propagule dispersal, fertilization, settlement, and recruitment are also influenced by water movement (Pearson & Brawley, 1996). In addition, increased water flow will cause scours though increased sediment movement affecting in particular small life stages of macroalgae 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). Increases in drag can however be counterbalanced in the long-term by changes in

morphology resulting in structurally more resistant thalli and holdfasts (Haring *et al.*, 2002).

An increase in water flow rate could also adversely affect this biotope. The mixed nature of the substratum means that suspended sediment of various sizes will be re-suspended and cobbles and pebbles are likely to move across the seabed. The movement of pebbles, cobbles and boulders across the sea floor may scour epilithic sponges, bryozoans and hydroids off the rocks and clumps of algae may become dislodged. Re-suspended sediments are likely to interfere with the suspension feeders feeding apparatus and respiratory currents to their detriment (see 'suspended sediment' pressure). In wave sheltered areas where this biotope occurs, the breadcrumb sponge *Halichondria panicea* grows in massive forms. Poorly attached massive forms may be ripped off by an increase in water flow rate leading to the death of large colonies.

Sensitivity assessment. Moderately strong tidal flow, characteristic of this biotope, encourages communities of sponges and ascidians. Changes to the hydrological regime are therefore likely to directly influence the presence of these species. As the biotope occurs in moderately strong tidal flow (0.5-1.5 m/s) an increase in water flow may result in disturbance or mobilization of the hard substrata (i.e. cobbles and pebbles), resulting in abrasion or loss of attached epilithic and epifauna. A reduction in water flow is likely to result in a loss of the suspension feeding species, an overall reduction in species richness, and result in loss of this biotope, as it is replaced by another *Fucus serratus* dominated biotope, e.g. LR.LLR.F.FserrX. However, a change of 0.1-0.2 m/s (the benchmark) is unlikely to adversely affect the biotope, although a reduction may decrease feeding and hence growth rates. Therefore, a resistance of 'High' is recorded, with a resilience of 'High' and a sensitivity of 'Not sensitive' at the benchmark level.

Emergence regime changes

Low

Q: High A: Medium C: Medium

Medium

Q: High A: High C: Medium

Medium

Q: High A: Medium C: Medium

This biotope group is found in the intertidal and is therefore subjected to cyclical immersion and emersion. *Fucus serratus* and *Chondrus crispus* are both intertidal species adapted to a degree of periodic desiccation. *Fucus serratus* is more susceptible to desiccation than other *Fucus* species located further up the shore and subjected more frequently to aerial exposure (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. In addition, early life history stages will be more susceptible than 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. Mortalities of other component of the community will however occur if the canopy is removed (see 'abrasion' pressure). Mathieson & Burns (1971) measured the photosynthetic rate of *Chondrus crispus* at varying degrees of desiccation and found that after loss of 65% of its water content, the rate of photosynthesis dropped to 55% of the control rate. In *Palmaria palmata*, 50% of the plant's water content can be lost in less than 4 hours in dry air at 25°C (Kain & Norton, 1990). This scenario can reasonably be expected at low tide in summer in Britain, although the *Fucus* canopy is likely to protect the underlying red algae to some extent. The upper shore extent of *Fucus serratus* and *Chondrus crispus* may be replaced by species more tolerant of desiccation and more characteristic of the mid-eulittoral such as *Fucus vesiculosus* or *Ascophyllum nodosum*.

A decrease in submergence is likely to adversely affect the suspension feeder population by reducing feeding opportunities as immersion is a prerequisite of feeding. This can prove fatal for short lived species such as bryozoans and ascidians. The tissue of *Halichondria panicea* holds some water and can tolerate a certain degree of desiccation. On the other hand, the soft bodied sea squirt *Asciidiella scabra* has a greater vulnerability to this pressure. The sea squirt is commonly found in damp crevices or under the canopy of macroalgae offering protection from desiccation but individuals at the highest point on the shore may dry out and die at the benchmark level.

On the other hand, an increase in submergence is likely to benefit this biotope. Feeding opportunity for suspension feeders will increase; desiccation and temperature stresses for all flora and fauna will decrease as will predation from birds. The biotope may extend further up the shore but this extension is likely to be counteracted by a reduction in the lower shore extent of the biotope likely to be taken over by seaweeds more characteristic of the sublittoral fringe. Furthermore, predation by the common shore crab *Carcinus maenas* is likely to increase.

Sensitivity assessment. Severe desiccation and associated osmotic stress can increase mortality in *Fucus serratus* (Pearson *et al.*, 2009). Other species better able to tolerate desiccation will competitively displace *Fucus serratus* following changes in emergence regime. The characterizing species of this biotope are largely protected from extreme levels of desiccation by the macroalgal canopy. However, the increase in emergence will result in loss of the extent of the biotope up the shore. Therefore, resistance is thus assessed as 'Low', resilience assessed as 'Medium', and the biotope assessed as 'Medium' sensitivity to changes in emersion regime at the level of the benchmark.

Wave exposure changes (local)

Medium

Q: High A: Low C: Medium

High

Q: High A: Low C: Medium

Low

Q: High A: Low C: Medium

Fucus serratus is highly flexible but not physically robust and an increase in wave exposure will cause mechanical damage, breaking fronds or even dislodging algae from the substratum. Fucoids are permanently attached to the substratum and are not 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. The biotope is found in wave sheltered to extremely sheltered habitats. In these locations, the breadcrumb sponge *Halichondria panicea* grows in massive forms. Poorly attached massive forms may be ripped off by an increase in water flow rate leading to the death of large colonies. A reduction in wave action would have little effect as the species is naturally found in wave sheltered conditions.

Sensitivity assessment. *Fucus serratus* and associated communities are sensitive to an increase in wave action as increased exposure would result in important losses both in biomass and species richness. The biotope may be preplaced by another *Fucus serratus* dominated biotope e.g. LR.MLR.BF.Fser. Resistance is thus assessed as 'Medium'. Recovery will depend on the extent of *Fucus serratus* loss but will be rapid once conditions return to normal if some of population remain, resulting in 'High' resilience. Overall this biotope group scores a 'Low' sensitivity to this pressure at the pressure benchmark.

Chemical Pressures

Resistance

Resilience

Sensitivity

Transition elements & organo-metal contamination

Not Assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

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

Hydrocarbon & PAH contamination

Not Assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

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

Synthetic compound contamination

Not Assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

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

Radionuclide contamination

No evidence (NEv)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

No evidence

Introduction of other substances

Not Assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

This pressure is **Not assessed**.

De-oxygenation

High

Q: Low A: NR C: NR

High

Q: High A: High C: High

Not sensitive

Q: Low A: Low C: Low

Sustained reduction of dissolved oxygen can lead to hypoxic (reduced dissolved oxygen) and anoxic (extremely low or no dissolved oxygen) conditions. Sustained or repeated episodes of reduced dissolved oxygen have the potential to severely degrade an ecosystem (Cole *et al.*, 1999). Josefson & Widbom (1988) investigated the response of benthic macro and meiofauna to reduced dissolved oxygen levels in the bottom waters of a fjord in Sweden. 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 deoxygenation.

Sensitivity assessment. Macroalgae may be negatively impacted by reduced dissolved oxygen level at the level of the benchmark (2 mg/l for 1 week) resulting in direct mortalities. However, the strong water movement in tide-swept tidal currents combined with turbulent flow over rocks would aerate the water column, and emersion at low tide would mean that any oxygen depletion was transient. Therefore, resistance is assessed as 'High'. Hence, resilience is assessed as 'High', and the biotope as 'Not sensitive'.

Nutrient enrichment**High**

Q: High A: High C: Medium

High

Q: High A: Low C: Medium

Not sensitive

Q: High A: Low C: Medium

Nutrient enrichment generally stimulates ephemeral macroalgae growth (Duarte, 1995). This stimulation of annual ephemerals may accentuate the competition for light and space and hinder perennial species development or harm their recruitment (Kraufvelin *et al.*, 2007). 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 the experiment. During the 4th year of exposure, however, *Fucus serratus* started to decline and population consequently crashed in the 5th year. The study observed full recovery of the algal canopy and animal community in less than 2 years after conditions returned to normal. The results indicate that established rocky shore communities of perennial algae with associated fauna are able to persist for several years, even at very high nutrient levels, but that community shifts may suddenly occur if eutrophication continues. They also indicate that rocky shore communities have the ability to return rapidly to natural undisturbed conditions after the termination of nutrient enhancement.

An influx of nutrients is also likely to stimulate phytoplankton production, depending on other environmental conditions. This means that the amount of food potentially available to the suspension feeders could increase but in the long-term, a sustained increase in nutrients could lead to algal blooms. Algal blooms have the potential to block light from underlying plants, thereby reducing their photosynthetic capacity. In addition, the eventual biodegradation of the blooms will result in the reduction of available oxygen causing reduced growth in macroalgae species such as *Fucus serratus*. Johansson *et al.* (1998) investigated the changes in the algal vegetation of the Swedish Skagerrak coast, an area heavily affected by eutrophication, between 1960 and 1997. Slow growing species, including *Chondrus crispus*, declined in abundance, probably due to competition from faster growing red algal species such as *Phycodrys rubens* and *Delesseria sanguinea*. However, this biotope occurs in areas with moderately strong to very strong tidal currents rapidly renewing depleted oxygen levels ('see 'de-oxygenation' pressure).

Sensitivity assessment. The benchmark of this pressure (compliance with WFD 'good' status) allows for a slightly less diverse community of red, green and brown seaweeds with cover variable depending on local physical conditions. Therefore, at the level of the benchmark both resistance and resilience are assessed as 'High'. The biotope group is, therefore 'Not Sensitive' to this pressure at the pressure benchmark.

Organic enrichment**Medium**

Q: Low A: NR C: NR

High

Q: High A: Low C: Medium

Low

Q: Low A: Low C: Low

Organic enrichment can stimulate the production of primary consumers and may lead to eutrophication (see 'nutrient enrichment' pressure). Husa *et al.* (2014) found that the macroalgal communities beyond the immediate proximity of fish farms in Hardangerfjord, Norway, seemed to be little affected by the deposition of organic matter from the salmon farming industry. Bellgrove *et al.* (2010) however determined that coralline turfs out-competed furoids at a site associated with organic enrichment caused by an ocean sewage outfall.

Sensitivity assessment. At the level of the benchmark, resistance is assessed as 'Medium' as some mortalities are likely to occur. Recovery will be rapid resulting in 'High' resilience score. The biotope has thus a 'Low' sensitivity to organic enrichment at the level of the benchmark.

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
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This biotope group occurs on hard substratum (boulders, pebbles and cobbles) on muddy sediment. A change towards a sedimentary substratum would lead to the direct loss of suitable attachment areas resulting in the loss of *Fucus serratus*, *Chondrus crispus* and other red seaweeds. The loss of macroalgae will result in the loss of habitat for associated sponge and ascidian communities. Resistance is assessed as 'None'. As this pressure represents a permanent change, recovery is impossible as suitable substratum for furoids is lacking. Consequently, resilience is assessed as 'Very low'. The habitat, therefore, scores a 'High' sensitivity. Although no specific evidence is described confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

Physical change (to another sediment type)	Low Q: High A: High C: High	Very Low Q: High A: Medium C: Medium	High Q: High A: Medium C: Medium
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This biotope group occurs on hard substratum (boulders, pebbles and cobbles) on muddy sediment. A change towards a soft sediment and loss of associated mixed hard substrata (boulders, pebbles and cobbles) would lead to the direct loss of suitable attachment areas resulting in the loss of *Fucus serratus*, *Chondrus crispus* and other red seaweeds. The loss of macroalgae will result in the loss of habitat for associated sponge and ascidian communities. Resistance is assessed as 'Low'. As this pressure represents a permanent change, recovery is impossible as suitable substratum for furoids is lacking. Consequently resilience is assessed as 'Very low'. The habitat therefore scores a 'High' sensitivity. Although no specific evidence is described confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

Habitat structure changes - removal of substratum (extraction)	None Q: Low A: NR C: NR	Low Q: High A: Low C: Medium	High Q: Low A: Low C: Low
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Extraction of sediment to 30 cm could remove the underlying sediment but also remove a proportion of the boulders, cobbles and pebbles on which the biotope develops, As a result the biotope could be lost or severely damaged, depending on the scale of the activity (see abrasion). Therefore, a resistance of 'None' is suggested. Resilience is probably 'Low', therefore the biotope is likely to have a 'High' sensitivity to this pressure.

Abrasion/disturbance of the surface of the substratum or seabed

Low

Q: High A: Medium C: High

Medium

Q: High A: Low C: Medium

Medium

Q: High A: Low C: Medium

The biotope group is found in the lower intertidal, an area easily accessible by humans especially at low tide. Most macroalgae are very flexible but not physically robust. The trampling of shores by humans will result in increased breakage of algal thalli, decreased thallus height and a net reduction in biomass (see Tyler-Walters & Arnold, 2005 for review).

In the UK, Boalch *et al.* (1974) and Boalch & Jephson (1981) noted a reduction in the cover of fucoids 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 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 fucoids (Boalch *et al.*, 1974). They suggested that the raised edges of the slaty rock severed fronds when the rocks were walked over. However, no quantitative data was provided.

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 m² per spring tide for 8 months between March and November. Using multivariate analysis, they noted that changes in the community dominated by fucoids (*Fucus vesiculosus*, *Fucus spiralis* and *Fucus serratus*) could be detected within 1 to 4 months of trampling, depending on intensity. Intensive trampling (160 steps/m² /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 fucoids was consistently lower in trampled plots than in untrampled plots. Fletcher and Frid (1996a) noted that the species composition of the algal community was changed by as little as 20 steps per m² per spring tide of continuous trampling since recolonization could not occur. A trampling intensity of 20 steps per m² 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 fucoids.

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 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). Fletcher & Frid (1996a; 1996b)

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. 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.

Algal turfs seem to be relatively tolerant of the direct effects of trampling (based on the available evidence) and some species may benefit from 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.

Conversely, furoid algae are particularly intolerant of trampling, depending on intensity. Furoid algae demonstrate a rapid (days to months) detrimental response to the effects of trampling, depending on species, which has been attributed to either the breakage of their fronds across rock surfaces (Boalch *et al.*, 1974) or their possession of small discoid holdfasts that offer little resistance to repeated impacts (Brosnan & Crumrine, 1992; Fletcher & Frid, 1996b). Foliose species such as *Mastocarpus papillatus*, *Pelvetiopsis limitata* and *Iridaea cornucopiae* are also likely to be intolerant of trampling (Brosnan & Crumrine, 1994). 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.

Once *Fucus serratus* has been removed, understory algae will become exposed. Macroalgae canopies buffer the effects of high temperatures and water loss on organisms below their fronds in particular when exposed to air. For instance Bertness *et al.* (1999) determined that substratum temperatures were on average 8-10°C lower under the canopy than on bare rock. Desiccation of understory algae will create bare patches (see 'changes in emergence regime' pressure). These bare patches can lead to invasions by grazing limpets which in turn can promote even greater changes in community composition (Little *et al.*, 2009). The removal of macroalgae canopy due to abrasion will thus have a direct impact on the entire community. However cracks and crevices are ideal places for germlings to develop and sessile species to settle as these sites may be protected from abrasion. Stagnol *et al.* (2013) found that opportunistic ephemeral green algae such as *Ulva* sp. responded positively to disturbance. These green ephemeral algae are major competitors of *Fucus serratus* for space colonization and nutrient uptake. Blooms of ephemeral algae facilitated by disturbance may then slow the development of longer-lived perennial algae, especially furoids. Disturbance is a structuring factor in intertidal habitats. Perturbation events often remove organisms, increase mortality, and release resources such as space, nutrients and light that may enhance the appearance of new colonists (Connell *et al.*, 1997). As a result of these contrasting effects, post-disturbance communities are frequently different from initial communities in terms of composition and dominance of species. Overall, disturbance causes a shift towards a disturbance tolerant seaweed community (Little *et al.*, 2009).

Epifaunal species have been found to be particularly adversely affected by physical disturbance, either due to direct damage or modification of the habitat (Jennings & Kaiser, 1998). Similarly,

Dayton (1971) observed greatly reduced abundance of species living on, under, and among fucoids following large disturbance events. Hydroids, bryozoans and encrusting fauna are easily ripped from the substratum and are unlikely to re-attach and will die. The shells of limpets, tubeworms andperiwinkles may be crushed by the weight and force of the abrasion. However, some epifaunal species have been reported to exhibit increased abundances on high fishing effort areas, probably due to their ability to colonize and grow rapidly (Bradshaw *et al.*, 2000). For instance *Ascidella* species had increased in abundance in an area subject to scallop dredging (Bradshaw *et al.*, 2002). The breadcrumb sponge *Halichondria panicea* is attached to the substratum and will not survive abrasion and physical disturbance. Hiscock (1983) noted that a community, under conditions of scour and abrasion from stones and boulders moved by storms, developed into a community consisting of fast growing species such as *Spirobranchus triqueter* due to decreased competition. A shift in community composition is thus expected immediately after the disturbance event.

The effects of trampling are dependent on intensity, expressed as frequency and force per unit area of the impacting 'foot print' (see Liddle, 1997, Tyler-Walters & Arnold, 2008). Clearly, mechanical abrasion due to vehicles, jack-up-barges, or grounding vessels will exceed the abrasive 'intensity' of trampling by humans or livestock. In addition, any potential abrasive activity that drags or moves across the substratum could overturn the boulders, cobbles and pebbles on which this biotope occurs, or even remove them from the area, resulting in significant damage or loss of the biotope.

Sensitivity assessment. Physical disturbance resulting from activities such as trampling (by humans and livestock) or abrasive activities (e.g. vehicles, jack-up-barges, or grounding vessels) could cause a significant loss of fucoid cover and an important reduction in species abundance and diversity. Resistance is thus assessed as 'Low'. If some of the *Fucus serratus* population remains recovery will be fairly rapid. However recruitment mortality, grazing by limpets and the presence of turfs and encrusting algae can slow down and limit recovery. Resilience is thus assessed as 'Medium'. The biotope, therefore, scores a 'Medium' sensitivity to abrasion pressure. If the entire population of *Fucus serratus* is removed, other species may come to dominate and the recovery will take considerably longer. Re-establishment of the seaweed may depend on the ability to out-compete other species and this may be dependent on suitable environmental conditions.

Penetration or disturbance of the substratum subsurface

None

Q: High A: Medium C: High

Medium

Q: High A: Low C: Medium

Medium

Q: High A: Low C: Medium

Penetrative activities (e.g. anchoring, scallop or suction dredging) are likely to remove or displace the cobbles, pebbles, or small boulders on which this biotope develops. As a result the biotope could be lost or severely damaged, depending on the scale of the activity (see abrasion above). Therefore, a resistance of 'None' is suggested. Resilience is probably 'Low', therefore the biotope is likely to be 'Highly' sensitive to this pressure.

Changes in suspended solids (water clarity)

Medium

Q: Medium A: Medium C: Medium

High

Q: High A: Low C: Medium

Low

Q: Medium A: Low C: Medium

Light is an essential resource for all photo-autotrophic organisms. Changes in suspended solids affecting water clarity will have a direct impact on the photosynthesising capabilities of *Fucus serratus*. Irradiance below light compensation point of photosynthetic species can compromise carbon accumulation (Middelboe *et al.*, 2006). However water clarity is only relevant when the

biotope is covered with water. Seaweed photosynthesis declines on emersion and recommences when recovered with water. In addition, increased siltation may cover the frond surface of *Fucus serratus* with a layer of sediment further reducing photosynthesis and growth rate. Sediment deposition can also interfere with attachment of microscopic stages of seaweeds reducing recruitment (see 'siltation' pressures). Red algae can tolerate a wider range of light levels than any other group of photosynthetic plants (Kain & Norton, 1990) and will therefore be less affected by a reduction in water clarity.

In turbid waters, the feeding apparatus of suspension feeders may become clogged with particles interfering with their feeding and respiratory currents resulting in net losses. For instance, the hydroid *Dynamena pumila* experienced marked decline in areas with increased silt content in Strangford Lough, Northern Ireland (Seed *et al.*, 1983). Some filter feeders have the ability to cope with siltation and excess suspended material. For example, the sea squirt *Ascidiella scabra* can extend its siphons to a small extent and can maintain a passage through the silt to the siphons. However Robbins (1985b) found that increased inorganic particulate concentrations reduced growth rates of *Ascidiella scabra* with mortalities occurring in high level of suspended sediments. The breadcrumb sponge *Halichondria panicea* has a cleaning mechanism sloughing off its complete outer tissue layer together with any debris (Barthel & Wolfrath, 1989). There is however an energetic cost in cleaning resulting in reduced growth. For short lived species, such as the star ascidian *Botryllus schlosseri*, reduced growth could prove fatal.

Sensitivity assessment. Changes in suspended solids reducing water clarity will have adverse effects on the biotope group reducing species richness. Resistance is thus assessed as 'Medium'. Once conditions return to 'normal' *Fucus serratus* is likely to rapidly regain photosynthesising capabilities as well as growth rate. Associated communities will also rapidly recover as most of the intolerant species produce planktonic larvae and are therefore likely to be able to recolonize quickly from surrounding areas. Resilience is thus assessed as 'High'. Overall this biotope group scores a 'Low' sensitivity to this pressure.

Smothering and siltation rate changes (light)

High

Q: High A: Medium C: Medium

High

Q: Medium A: Medium C: Medium

Not sensitive

Q: Medium A: Medium C: Medium

Macroalgae are attached to the substratum by a holdfast and are thus not able to relocate in response to increased sedimentation. Sedimentation of bedrock can impede attachment of *Fucus* embryos as well as decrease survival and growth of juvenile through both scour and burial (Schiel *et al.*, 2006). An increase in the vertical sediment overburden can also reduce growth whilst hindering the regeneration abilities of adults (Umar *et al.*, 1998).

Some filter feeders have the ability to cope with siltation and excess suspended material. For example, *Ascidiella scabra* can extend its siphons, to a small extent, above silt whilst maintaining a passage through the silt to the siphons. It also attaches to other erect biota and may thereby escape smothering effects. The breadcrumb sponge *Halichondria panicea* has a mechanism for sloughing off its complete outer tissue layer together with any debris (Barthel & Wolfrath, 1989). However, there is an energetic cost in cleaning, and this species, together with other filter feeders, would probably experience reduced. For annual species, including the star ascidian *Botryllus schlosseri*, reduced growth could prove fatal. The hydroid *Dynamena pumila* experienced marked decline in areas with increased silt content in Strangford Lough, Northern Ireland (Seed *et al.*, 1983).

Sensitivity assessment. Smothering by a 5 cm layer of sediment is unlikely to adversely affect this

biotope given that it is associated with areas of moderately strong to very strong tidal flow. The sediment layer will be washed away and 'normal' conditions will resume rapidly. The suspension feeders may experience some short lived interference with feeding but, at the level of the benchmark, this is not likely to adversely affect their viability. Resistance and resilience are therefore both assessed as 'High' (no impacts to recover from). The biotope group is 'Not Sensitive' to a decrease in salinity at the pressure benchmark.

Smothering and siltation rate changes (heavy)

Low

Q: High A: Low C: Medium

Medium

Q: Low A: NR C: NR

Medium

Q: Low A: NR C: NR

Several studies found that increasing the vertical sediment burden negatively impact species characterizing this biotope. At the level of the benchmark (30 cm of fine material added to the seabed in a single event) smothering will result in important mortalities. Resistance is assessed as 'Low' as all individuals exposed to siltation at the benchmark level are predicted to die. However the biotope is associated with areas of moderately strong to very strong tidal flow. The sediment layer will be washed away and 'normal' conditions will resume rapidly. Resilience is thus assessed as 'Low' and resistance as 'Medium'. Sensitivity based on combined resistance and resilience is therefore assessed as 'Medium'.

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 biotope do not have hearing perception but vibrations may cause an impact, however no studies exist to support an assessment

Introduction of light or shading

Medium

Q: High A: Low C: Medium

High

Q: High A: Medium C: Medium

Low

Q: High A: Low C: Medium

Fucoids are dependent on light, 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. There is considerable literature on the light compensation point of marine algae (see Luning, 1990) but it is difficult to correlate such evidence with 'shading', as light saturation and compensation points depend on light availability, light quality, season and turbidity. As fucoids are out-competed in sublittoral conditions, it is likely that permanent shading would affect their growth and allow them to be out-competed by other, more shade tolerant species, within the affected area. Therefore a resistance of 'Medium' is suggested albeit at low confidence. Resilience is likely to be 'High' so that sensitivity is 'Low'.

Barrier to species movement

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

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

Death or injury by collision

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

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 group.

Introduction or spread of invasive non-indigenous species

Medium

Q: High A: Medium C: Medium

Low

Q: Low A: NR C: NR

Medium

Q: Low A: NR C: NR

Thompson & Schiel (2012) found that native fucoids showed high resistance to invasions by the Japanese kelp *Undaria pinnatifida*. However cover of *Fucus serratus* was inversely correlated with the cover of *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. The Portuguese oyster *Magallana gigas* was introduced in England in 1926 for cultivation purposes and is now found in the wild. The species can form dense beds e.g. in the Netherlands, and, together with *Crepidula fornicata*, have the potential to cover large patches on the shore. In areas where the biotope coincides with the distribution of *Magallana gigas*, i.e. the south coast of Devon and coast of Essex, the oyster may become dominant.

Sensitivity assessment. Resistance is assessed as ‘Medium’ since invasive species have the potential to alter the recognizable biotope. Recovery would be rapid once conditions return to normal, resulting in a ‘High’ resilience. However, return to ‘normal’ conditions is highly unlikely if an invasive species would come to dominate the biotope. Indeed recovery would only be possible if

the majority of the INIS were removed (through either natural or unnatural process) to allow the re-establishment of other species. Therefore actual resilience will be much lower ('Low' to 'Very Low') resulting in an overall 'Medium' sensitivity score.

Introduction of microbial pathogens

High

Q: Low A: NR C: NR

High

Q: Low A: NR C: NR

Not sensitive

Q: Low A: NR C: NR

Very little is known about infections in *Fucus* (Wahl *et al.*, 2012). Coles (1958) identified parasitic nematodes that caused galls on *Fucus serratus* in the Southwest of Britain. 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). Other characteristic species, for example *Chondrus crispus* and *Mytilus edulis* are known to be adversely affected by infestation by microbial pathogens (see relevant MarLIN reviews). However, even if microbial infestation resulted in the loss of these two species from the biotope, the recognizable biotope per se would not be affected.

Sensitivity assessment. Both resistance and resilience are assessed as 'High'; the biotope is therefore 'Not Sensitive' to this pressure. However the assessment has a low confidence score as more research is needed into the effects of microbial pathogen on *Fucus serratus* and associated communities.

Removal of target species

Low

Q: Low A: NR C: NR

Medium

Q: High A: Medium C: Medium

Medium

Q: Low A: Low C: Low

Fucus serratus is one of several harvested and exploited algal species. Seaweeds were collected from the middle of the 16th century for the iodine industry. Nowadays seaweeds are harvested for their alginates, which are used in the cosmetic and pharmaceutical industries, for agricultural supply, water treatment, and for human food and health supplements (Bixler & Porse, 2010).

The commercial harvest removes seaweed canopies which will have important direct and indirect effects on the wider ecosystem. Stagnol *et al.* (2013) investigated the effects of commercial harvesting of intertidal *Fucus serratus* on ecosystem biodiversity and functioning. The study found that the removal of macroalgae 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. Suspension feeders were the most affected by the canopy removal as canopy-forming algae are crucial habitats for these species, most of them being sessile organisms.

Other studies confirm that loss of canopy had both short and long-term consequences for benthic communities in terms of diversity resulting in shifts in community composition and a loss of ecosystem functioning such as primary productivity (Lilley & Schiel, 2006; Gollety *et al.*, 2008). Removal of the canopy caused bleaching and death of understorey red turfing algae. Stagnol *et al.* (2013) observed *Patella vulgata* recruiting in bare patches of disturbed plots. Experimental studies have shown that limpets control the development of macroalgae by consuming microscopic phases (Jenkins *et al.*, 2005) or the adult stages (Davies *et al.*, 2007). The increase in *Patella vulgata* abundance could thus limit the recruitment and growth of *Fucus serratus* on the impact zone. Due to the high intolerance of macroalgae communities to human exploitation, the European Union put in place a framework to regulate the exploitation of algae establishing an organic label

that implies that 'harvest shall not cause any impact on ecosystems' (no. 710/2009 and 834/2007).

Sensitivity assessment. Removal of the *Fucus serratus* canopy will have a negative impact on the diversity of animal community and the metabolism of the area. The harvesting impact on the animal community was amplified by the settlement of an ephemeral canopy of *Ulva* spp., a seasonal opportunistic green alga (Stagnol *et al.*, 2013). Resistance is thus assessed as 'Low'. If some *Fucus serratus* population remain recovery will be fairly rapid. However recruitment mortality, grazing by limpets and the presence of turfs and encrusting algae can slow down and limit recovery. A switch to a disturbance community will also slow the recovery of *Fucus serratus* and associated community. Resilience is thus assessed as 'Medium'. The biotope therefore scores a 'Medium' sensitivity to this pressure. If the entire population of *Fucus serratus* is removed, other species may come to dominate and the recovery will take considerably longer. Re-establishment of the seaweed may depend on the ability to out-compete other species and this may be dependent on suitable environmental conditions.

Removal of non-target species

High

Q: Low A: NR C: NR

High

Q: High A: High C: High

Not sensitive

Q: Low A: Low C: Low

The harvest of algae, crabs snails, mussels, and some species of fish from the shore is a widespread practice. None of the components of this biotope have known obligate relationships and the removal of non-target species will therefore not have a significant impact. Resistance to this pressure is deemed 'High'. Resilience is also 'High' as there are no ecological impacts to recover from, resulting in a 'Not Sensitive' score. The assessment is based on expert knowledge resulting in a 'Low' confidence score.

Components of this biotope may be directly removed or damaged by static or mobile gears that are targeting other species. These direct, physical impacts are assessed through the abrasion and penetration of the seabed pressures. The sensitivity assessment for this pressure considers any biological/ecological effects resulting from the removal of non-target species on this biotope.

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