# Red seaweeds and kelps on tide-swept mobile infralittoral cobbles and pebbles

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

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**Red seaweeds and kelps on tide-swept mobile infralittoral cobbles and pebbles**
**Photographer:** Keith Hiscock
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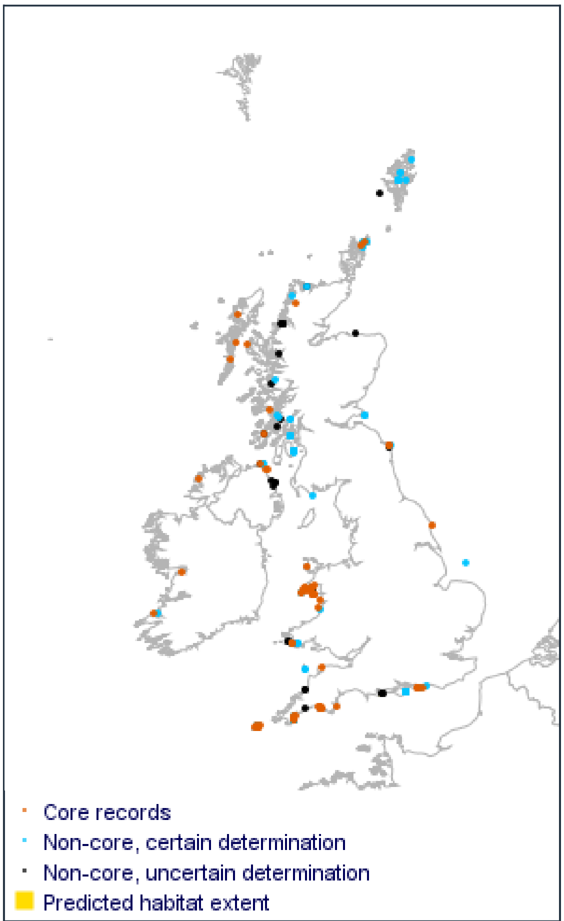


17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

**Researched by** Thomas Stamp **Refereed by** Admin

# Summary

## UK and Ireland classification

| | | |
|---|---|---|
| **EUNIS 2008** | A5.5211 | Red seaweeds and kelps on tide-swept mobile infralittoral cobbles and pebbles |
| **JNCC 2015** | SS.SMp.KSwSS.SlatR.CbPb | Red seaweeds and kelps on tide-swept mobile infralittoral cobbles and pebbles |
| **JNCC 2004** | SS.SMp.KSwSS.LsacR.CbPb | Red seaweeds and kelps on tide-swept mobile infralittoral cobbles and pebbles |
| **1997 Biotope** | IR.MIR.SedK.EphR | Ephemeral red seaweeds and kelps on tide-swept mobile infralittoral cobbles |

## Description

Tide-swept infralittoral cobbles and pebbles which are highly mobile, create an environment that is difficult for many algae to survive in. Foliose and filamentous seaweeds with an encrusting phase in their life history, or those that are able to withstand rolling of the substratum and scouring can form dense turfs of seaweed. Characteristic species include *Schmitzia* spp., *Lomentaria orcadensis*, *Halarachnion ligulatum* and *Taonia atomaria*. In addition, ephemeral algae grow rapidly in periods of relative stability. Scattered *Laminaria* and *Desmarestia* plants may also be present on the more stable substrata. Some areas of cobbles may be quite barren, dominated only by encrusting coralline algae and brittlestars. The faunal component of this biotope maybe relatively sparse. Turfs of hydroids (*Nemertesia* spp.) and bryozoans (*Crisia* spp. and *Bugula* spp.) are the major components.

## Depth range

5-10 m, 10-20 m

## Additional information

-

## Listed By

- none -

## Further information sources

Search on:

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# Sensitivity review

## Sensitivity characteristics of the habitat and relevant characteristic species

SS.SMp.KSwSS.SlatR (plus sub-biotopes) and SS.SMp.KSwSS.SlatCho typically occur on a mixture of shallow sediments and rock fractions. The mobility of the sediment and rock fractions allow *Saccharina latissima* (syn *Laminaria saccharina*), *Chorda filum* and other red and brown seaweeds to grow on small stones and shells. *Saccharina latissima* and *Chorda filum* are important canopy forming species within these biotopes. Four sub-biotopes are present within the SS.SMp.KSwSS.SlatR biotope complex, which are largely distinguished by the degree of tidal flow and wave action. As the degree of wave and/or tidal exposure decreases there is a change in community structure, with the density of *Saccharina latissima* and the diversity of red algal species increasing. A decrease in tidal flow results in increased sediment stability which in turn facilitates mature macro-algae communities.

In undertaking this assessment of sensitivity, account is taken of knowledge of the biology of all characterizing species in the biotope. For this sensitivity assessment *Saccharina latissima*, *Chorda filum* are the primary foci of research, however it is recognized that the red seaweed communities of SS.SMp.KSwSS.SlatR also define these biotopes. Examples of important species groups are mentioned where appropriate.

## Resilience and recovery rates of habitat

*Saccharina latissima* (syn. *Laminaria saccharina*) and *Chorda filum* are opportunistic seaweeds which have relatively fast growth rates. *Saccharina lattisima* is a perennial kelp which can reach maturity in 15-20 months ((Sjøtun, 1993) and has a life expectancy of 2-4 years (Parke, 1948). *Chorda filum* is an annual seaweed, completing its life cycle in a single season (Novaczek *et al*., 1986). *Saccharina lattisima* is widely distributed in the north Atlantic from Svalbard to Portugal (Birket *et al.*, 1998; Connor *et al*., 2004; Bekby & Moy 2011; Moy & Christie 2012). *Chorda filum* is widely distributed across the northern hemisphere (Algae Base, 2015). In the North Atlantic, *Chorda filum* is recorded from Svalbard (Fredriksen *et al*., 2014) to Northern Portugal (Araújo *et al*, 2009).

*Saccharina lattisima* and *Chorda filum* have heteromorphic life strategies (Edwards, 1998). Mature sporophytes broadcast spawn zoospores from reproductive structures known as sori (South & Burrows, 1967; Birket et al., 1998). Zoospores settle onto rock and develop into gametophytes, which following fertilization germinate into juvenile sporophytes. *Laminarian* zoospores are expected to have a large dispersal range. However, zoospore density and the rate of successful fertilization decreases exponentially with distance from the parental source (Fredriksen *et al*., 1995). Hence, recruitment can be influenced by the proximity of mature kelp beds producing viable zoospores (Kain, 1979; Fredriksen *et al*., 1995). *Saccharina lattisma* recruits appear in late winter early spring beyond which is a period of rapid growth, during which sporophytes can reach a total length of 3 m (Werner & Kraan, 2004). In late summer and autumn, growth rates slow and spores are released from autumn to winter (Parke, 1948; Lüning, 1979; Birket *et al*., 1998). The overall length of the sporophyte may not change during the growing season due to marginal erosion but the growth of the blade has been measured at 1.1 cm/day, with a total length addition of ≥2.25 m per year (Birkett *et al*., 1998). *Chorda filum* recruits appear from February (South & Burrows, 1967) after which is a period of rapid growth during which sporophytes can reach a length of ≤6 m (South & Burrows, 1967). In culture, *Chorda filum* can reach reproductive maturity and produce zoospores within 186 days (ca 6 months) of settlement but the time taken to reach maturity may be locally variable (South & Burrows, 1967). In nature, sporophytes growth slows/stops from October and sporophytes may begin to die off (South & Burrows, 1967; Novaczek *et al*., 1986).

*Saccharina lattisma* can be quite ephemeral in nature and appear early in algal succession. For example, Lienaas & Christie (1996) removed *Strongylocentrotus droebachiensis* from "Urchin Barrens" and observed a succession effect. Initially, the substratum was colonized by filamentous algae, after a couple of weeks these were out-competed and the habitat dominated by *Saccharina latissimi*. However, this was subsequently out-competed by *Laminaria hyperborea*. In the Isle of Man, Kain (1975) cleared sublittoral blocks of *Laminaria hyperborea* at different times of the year for several years. The first colonizers and succession community differed between blocks and at what time of year the blocks were cleared. *Saccharina lattisma* was an early colonizer, but within 2 years of clearance, the blocks were dominated by *Laminaria hyperborea*.

In 2002, a 50.7-83% decline of *Saccharina latissima* was discovered in the Skaggerak region, South Norway (Moy *et al*., 2006; Moy & Christie, 2012). Survey results indicated a sustained shift from *Saccharina latissima* communities to those of ephemeral filamentous algal communities. The reason for the community shift was unknown, but low water movement in wave and tidally sheltered areas combined with the impacts of dense human populations e.g. increased land run-off, was suggested to be responsible for the dominance of ephemeral turf macro-algae. Multiple stressors such as eutrophication, increasing regional temperature, increased siltation and overfishing may also be acting synergistically to cause the observed habitat shift.

**Resilience assessment.** *Saccharina latissima*, *Chorda filum* have the potential to rapidly recover following disturbance. *Saccharina latissima* has been shown to be an early colonizer within algal succession, appearing within 2 weeks of clearance, and can reach sexual maturity within 15-20 months. *Chorda filum* has rapid growth rates, capable of reaching sexual maturity within a year. Resilience has therefore been assessed as '**High**'.

## Hydrological Pressures

| | Resistance | Resilience | Sensitivity |
|---|---|---|---|
| **Temperature increase (local)** | None<br>Q: High A: High C: High | High<br>Q: High A: High C: High | Medium<br>Q: High A: High C: High |

The temperature isotherm of 19-20°C has been reported as limiting *Saccharina latissima* geographic distribution (Müller *et al*., 2009). Gametophytes can develop in ≤23°C (Lüning, 1990) however, the optimal temperature range for sporophyte growth is 10-15 °C (Bolton & Lüning, 1982). Bolton & Lüning (1982) experimentally observed that sporophyte growth was inhibited by 50-70% at 20°C and following 7 days at 23°C all specimens completely disintegrated. In the field *Saccharina latissima* has shown significant regional variation in its acclimation to temperature changes, for example Gerard & Dubois (1988) observed sporophytes of *Saccharina latissima* which were regularly exposed to ≥20°C could tolerate these temperatures, whereas sporophytes from other populations which rarely experience ≥17°C showed 100% mortality after 3 weeks of exposure to 20 °C. Therefore, the response of *Saccharina latissima* to a change in temperatures is likely to be locally variable.

In experiments, Lüning (1980) observed that *Chorda filum* could not reproduce at 15-20 °C but found that sporophytes could tolerate ≤26 °C.

Northern to southern Sea Surface Temperature (SST) ranges from 8-16 °C in summer and 6-13 °C in winter in the UK (Beszczynska-Möller & Dye, 2013). The effect of this pressure is likely to be regionally variable.

**Sensitivity assessment.** Ecotypes of *Saccharina lattisima* have been shown to have different temperature optimums (Dubois, 1988). Both a 2 & 5°C increase in temperature, when combined with high UK summer temperatures in the south of the UK, could cause large scale mortality of *Saccharina lattisima* and inhibit *Chorda filum* reproduction. Resistance has been assessed as '**None**', Resilience as '**High**'. Sensitivity has been assessed as '**Medium**'.

| | | | |
|---|---|---|---|
| **Temperature decrease (local)** | High<br>Q: High A: High C: High | High<br>Q: High A: High C: High | Not sensitive<br>Q: High A: High C: High |

*Saccharina lattissima* and *Chorda filum* are widespread throughout the arctic. *Saccharina lattissima* has a lower temperature threshold for sporophyte growth at 0 °C (Lüning, 1990). *Chorda filum* sporophytes can also tolerate 0 °C, Novaczek *et al.*, (1986) observed that 99% of newly settled zoospores died at 0 °C but sporophytes transferred from 5 °C to 0 °C remained healthy and continued to grow for a period of 2 months. Novaczek *et al.*, (1986) therefore demonstrated that sporophytes could tolerate exposure to low (≥0°C) temperatures, but that exposure could have negative effects on larval survival and recruitment processes. Subtidal red algae can survive at -2°C (Lüning, 1990; Kain & Norton, 1990). The distribution and temperature tolerances of these species suggest they likely be unaffected by temperature decreases assessed within this pressure.

**Sensitivity assessment.** Resistance has been assessed as '**High**', resilience as '**High**'". Sensitivity has been assessed as '**Not Sensitive**'.

| | | | |
|---|---|---|---|
| **Salinity increase (local)** | Medium<br>Q: Low A: NR C: NR | High<br>Q: High A: High C: High | Low<br>Q: NR A: NR C: NR |

Karsten (2007) tested the photosynthetic ability of *Saccharina latissima* under acute 2 and 5 day exposure to salinity treatments ranging from 5-60 psu. A control experiment was also carried at 34 psu. *Saccharina latissima* showed high photosynthetic ability at >80% of the control levels between 25-55 psu. However, Birkett et al. (1998) suggested that kelps are stenohaline and therefore long-term increases in salinity may be detrimental.

*Chorda filum* can be found in rock pools (South & Burrows, 1967). High air temperatures cause surface evaporation of water from rock pools so that salinity steadily increases. The extent of temperature and salinity change is affected by the frequency and time of day at which tidal inundation occurs. If high tide occurs in early morning and evening the diurnal temperature follows that of the air, whilst high water at midday suddenly returns the temperature to that of the sea (Pyefinch, 1943). It should be noted however that local populations may be acclimated to the prevailing salinity regime and may, therefore, exhibit different tolerances to other populations subject to different salinity conditions and therefore caution should be used when inferring tolerances. However, it is likely that *Chorda filum* is tolerant of short-term salinity increases.

**Sensitivity assessment**. The evidence suggests that *Saccharina latissima* and *Chorda filum* can tolerate short-term exposure to hypersaline conditions (≥40‰-MNCR full salinity). An increase in salinity to ≥40‰ may, however, be above the optima for characterizing species and cause a decline in growth, and possibly loss of red algae and a reduction in species diversity.  Resistance has been assessed as '**Medium**', resilience as '**High**'. The sensitivity of this biotope to an increase in salinity has been assessed as ‘**Low**’.

| | | | |
|---|---|---|---|
| **Salinity decrease (local)** | Medium<br>Q: High A: High C: High | High<br>Q: High A: High C: High | Low<br>Q: High A: High C: High |

Karsten (2007) tested the photosynthetic ability of *Saccharina latissima* under acute 2 and 5 day exposure to salinity treatments ranging from 5-60 psu. A control experiment was also carried at 34 psu. *Saccharina latissima* showed high photosynthetic ability at >80% of the control levels between 25-55 psu. Hyposaline treatment of 10-20 psu led to a gradual decline of photosynthetic ability. After 2 days at 5 psu, *Saccharina latissima* showed a significant decline in photosynthetic ability at approx. 30% of control. After 5 days at 5 psu, *Saccharina latissima* specimens became bleached and showed signs of severe damage. The experiment was conducted on *Saccharina latissima* from the Arctic, and the authors suggest that at extremely low water temperatures (1-5°C) macroalgae acclimation to rapid salinity changes could be slower than at temperate latitudes. It is, therefore, possible that resident *Saccharina latissima* of the UK maybe be able to acclimate to salinity changes more effectively.

*Chorda filum* is tolerant of low salinities (Wilce, 1959; Hayren, I940; Norton & South, 1969), and has been recorded at Björnholm, Finland at a salinity as low as 5.15%o (Hayren, I940). Norton & South (1969) observed that *Chorda filum* could develop sporophytes at ≥5‰ under laboratory conditions, however at low salinities, the time taken to develop into sporophytes took 65 days at 5‰ or 16 days at 35‰. It was also noted that below 9‰ sporophytes did not grow above 2 mm in length.

**Sensitivity assessment.** A decrease in one MNCR salinity scale from “Full Salinity” (30-40 psu) to “Reduced Salinity” (18-30 psu) would inhibit *Saccharina lattissima* photosynthesis and hence growth. *Chorda filum* is highly tolerant of low salinity and is unlikely to be affected at the benchmark level. However, a shift to reduced salinity conditions is likely to result in a change in the infauna community and an overall reduction in species diversity. Therefore, resistance has been assessed as ‘**Medium**’ resilience as ‘**High**’. The sensitivity of this biotope to a decrease in salinity has been assessed as ‘**Low**’.

| | | | |
|---|---|---|---|
| **Water flow (tidal current) changes (local)** | High<br>Q: High A: High C: High | High<br>Q: High A: High C: High | Not sensitive<br>Q: High A: High C: High |

Peteiro & Freire (2013) measured *Saccharina latissima* growth from 2 sites, the 1st had maximal water velocities of 0.3 m/sec and the 2nd 0.1 m/sec. At site 1 *Saccharina latissima* had significantly larger biomass than at site 2 (16 kg/m to 12 kg/m respectively). Peteiro & Freire (2013) suggested that faster water velocities were beneficial to *Saccharina latissima* growth. However, Gerard & Mann (1979) measured *Saccharina latissima* productivity at greater water velocities and found *Saccharina latissima* productivity is reduced in moderately strong tidal streams (≤1 m/sec) when compared to weak tidal streams (<0.5 m/sec).

*Chorda filum* sporophytes often grow on unstable objects, such as pebbles and shell. Owing to the typically unstable substratum which *Chorda filum* grows on, whole populations can be moved during storms and deposited in more sheltered locations where development will continue (South & Burrows, 1967). The survival of *Chorda filum* sporophytes following transport of their attached substrata indicates the species is relatively tolerant to changes in water flow or wave action.

As highlighted by Connor *et al.*, (2004) large increases in tidal flow (>0.5 m/s) are likely to influence biotope structure and smaller changes in tidal flow (e.g. 0.1-0.2m/s) are not likely to have a significant effect on the characterizing species. A change in the tidal flow of 0.1-0.2 m/sec in low energy biotopes e.g. SS.SMp.KSwSS.SlatR.Mu, may, however, remove finer sediment fractions (e.g. mud) and may, therefore, change the biotope. However, the evidence is lacking and a change in tidal velocities is not likely to result in a significant change to the dominant species.

**Sensitivity assessment.** Resistance has been assessed as '**High**', resilience as '**High**'. Sensitivity has been assessed as '**Not Sensitive**'.

| | | | |
|---|---|---|---|
| **Emergence regime changes** | Medium<br>Q: Medium A: High C: High | High<br>Q: High A: Low C: High | Low<br>Q: Medium A: Low C: High |

SS.SMp.KSwSS.SlatR and SS.SMp.KSwSS.SlatCho are recorded from 0-10m, while SlatR can extend to 20m (Connor *et al.*, 2004). Therefore, the upper limit of the biotopes in the sublittoral fringe (South & Burrows, 1967; White & Marshall, 2007) could be exposed during some low tides.

An increase in emergence will result in an increased risk of desiccation and mortality of *Saccharina latissima* and *Chorda filum*. Removal of macroalgae canopy may also increase desiccation and mortality of the undergrowth red seaweed community (Hawkins & Harkin, 1985). Providing that suitable substrata are present, the biotope is likely to re-establish further down the shore within a similar emergence regime to that which existed previously.

**Sensitivity assessment**. Resistance has been assessed as '**Medium**'. Resilience as '**High**'. The sensitivity of this biotope to a change in emergence is considered as '**Low**'.

| | | | |
|---|---|---|---|
| **Wave exposure changes (local)** | High<br>Q: High A: High C: High | High<br>Q: High A: High C: High | Not sensitive<br>Q: High A: High C: High |

Birkett *et al.* (1998b) suggested that *Saccharina latissima* is rarely present in areas of wave exposure, where it is out-competed by *Laminaria hyperborea*. *Chorda filum* sporophytes often grow on unstable objects, such as pebbles and shell. Owing to the typically unstable substratum which *Chorda filum* grows on, whole populations can be moved during storms and deposited in more sheltered locations where development will continue (South & Burrows, 1967).

A large increase in near-shore wave height is likely to significantly influence biotope structure. As highlighted by Connor *et al.* (2004), sub-biotopes within SS.SMp.KSwSS.SlatR are largely distinguished by wave exposure

**Sensitivity assessment.** A large scale increase in local wave height may increase local sediment mobility, potentially increase dislodgment or relocation of the characterizing species (South & Burrows, 1967; Birkett *et al.*, 1998b). However, an increase in nearshore significant wave height of 3-5% is not likely to have a significant effect on biotope structure. Resistance has been assessed as '**High**', Resilience as '**High**'. Sensitivity has been assessed as '**Not Sensitive**' at the benchmark level.

## Chemical Pressures

| | Resistance | Resilience | Sensitivity |
|---|---|---|---|

| | | | |
|---|---|---|---|
| **Transition elements & organo-metal contamination** | Not Assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR |

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

Bryan (1984) suggested that the general order for heavy metal toxicity in seaweeds is: Organic Hg > inorganic Hg > Cu > Ag > Zn > Cd > Pb. Cole *et al.*, (1999) reported that Hg was very toxic to macrophytes. Similarly, Hopkin & Kain (1978) demonstrated sub-lethal effects of heavy metals on kelp gametophytes and sporophytes, including reduced growth and respiration. Sheppard *et al.* (1980) noted that increasing levels of heavy metal contamination along the west coast of Britain reduced species number and richness in holdfast fauna, except for suspension feeders which became increasingly dominant. Gastropods may be relatively tolerant of heavy metal pollution (Bryan, 1984). Although macroalgae species may not be killed, except by high levels of contamination, reduced growth rates may impair the ability of the biotope to recover from other environmental disturbances. Thompson & Burrows (1984) observed the growth of *Saccharina latissima* sporophyte growth was significantly inhibited at 50 µg Cu /l, 1000 µg Zn/l and 50 µg Hg/l. Zoospores were found to be more intolerant and significant reductions in survival rates were observed at 25 µg Cu/l, 1000 µg Zn/l and 5 µg/l.

| | | | |
|---|---|---|---|
| **Hydrocarbon & PAH contamination** | Not Assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR |

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

The mucilaginous slime layer coating of *Laminarians* may protect them from smothering by oil. Hydrocarbons in solution reduce photosynthesis and may be algicidal. However, Holt *et al.* (1995) reported that oil spills in the USA and from the *Torrey Canyon* had little effect on kelps. Similarly, surveys of subtidal communities at a number sites between 1-22.5 m below chart datum showed no noticeable impacts of the Sea Empress oil spill and clean up (Rostron & Bunker, 1997) or during the experimental release of untreated oil in Baffin Island, Canada (Cross *et al.*, 1987). Laboratory studies of the effects of oil and dispersants on several red algae species (Grandy 1984) concluded that they were all sensitive to oil/ dispersant mixtures, with little differences between adults, sporelings, diploid or haploid life stages.

| | | | |
|---|---|---|---|
| **Synthetic compound contamination** | Not Assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR |

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

O'Brian & Dixon (1976) suggested that red algae were the most sensitive group of macrophytes to oil and dispersant contamination (see Smith, 1968). *Saccharina latissima* has also been found to be sensitive to antifouling compounds. Johansson (2009) exposed samples of *Saccharina latissima* to several antifouling compounds, observing chlorothalonil, DCOIT, dichlofluanid and tolylfluanid inhibited photosynthesis. Exposure to Chlorothalonil and tolylfluanid was also found to continue inhibiting oxygen evolution after exposure had finished, and may cause irreversible damage.

Smith (1968) observed that epiphytic and benthic red algae were intolerant of dispersant or oil contamination during the Torrey Canyon oil spill; only the epiphytes *Crytopleura ramosa* and

*Spermothamnion repens* and some tufts of *Jania rubens* survived together with *Osmundea pinnatifida*, *Gigartina pistillata* and *Phyllophora crispa* from the sublittoral fringe.

| | | | |
|---|---|---|---|
| **Radionuclide contamination** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | No evidence (NEv)<br>Q: NR A: NR C: NR |

**No Evidence**

| | | | |
|---|---|---|---|
| **Introduction of other substances** | Not Assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR |

This pressure is **Not assessed**.

| | | | |
|---|---|---|---|
| **De-oxygenation** | High<br>Q: Medium A: High C: High | High<br>Q: Medium A: High C: High | Not sensitive<br>Q: Medium A: High C: High |

Reduced oxygen concentrations can 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). A rapid recovery from a state of low oxygen is expected if the environmental conditions are transient. If levels do drop below 4 mg/l negative effects on these organisms can be expected with adverse effects occurring below 2mg/l (Cole *et al*., 1999).

**Sensitivity Assessment.** Reduced oxygen levels are likely to inhibit photosynthesis and respiration but not cause a loss of the macroalgae population directly. Resistance has been assessed as '**High**', Resilience as '**High**'. Sensitivity has been assessed as '**Not sensitive**' at the benchmark level.

| | | | |
|---|---|---|---|
| **Nutrient enrichment** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not sensitive<br>Q: NR A: NR C: NR |

Conolly & Drew (1985) found *Saccharina latissima* sporophytes had relatively higher growth rates when in close proximity to a sewage outlet in St Andrews, UK, compared to other sites along the east coast of Scotland. At St Andrews, nitrate levels were 20.22μM, which represents an approx. 25% increase compared to other sites (approx. 15.87 μM). Handå *et al.* (2013) also reported *Saccharina latissima* sporophytes grew approx. 1% faster per day when in close proximity to Norwegian salmon farms, where elevated ammonium could be readily absorbed by sporophytes. Read *et al*. (1983) reported after the installation of a new sewage treatment works, which reduced the suspended solid content of liquid effluent by 60% in the Firth of Forth, *Saccharina latissima* became abundant where previously it had been absent. Bokn *et al.* (2003) conducted a nutrient loading experiment on intertidal fucoids. Within 3 years of the experiment no significant effect was observed in the communities, however, 4-5 years into the experiment a shift occurred from perennials to ephemeral algae. Although Bokn *et al.* (2003) focussed on fucoids the results could indicate that long-term (>4 years) nutrient loading can result in community shift to ephemeral algae species. Disparities between the findings of the aforementioned studies are likely to be related to the level of organic enrichment.

Johnston & Roberts (2009) conducted a meta-analysis, which reviewed 216 papers to assess how a variety of contaminants (including sewage and nutrient loading) affected 6 marine habitats (including subtidal reefs). A 30-50% reduction in species diversity and richness was identified from all habitats exposed to the contaminant types. Johnston & Roberts (2009) ,however, also highlighted that macroalgal communities are relatively tolerant to contamination, but that contaminated communities can have low diversity assemblages which are dominated by opportunistic and fast growing species (Johnston & Roberts, 2009 and references therein).

**Sensitivity assessment.** Although short-term exposure (<4 years) to nutrient enrichment may not affect seaweeds directly, indirect effects such as turbidity may significantly affect photosynthesis and result in reduced growth and reproduction and increased competition form fast growing but ephemeral species. However, this biotope is considered to be '**Not sensitive**' at the pressure benchmark, that assumes compliance with good status as defined by the WFD.

| | | | |
|---|---|---|---|
| **Organic enrichment** | Medium<br>Q: Medium A: High C: High | High<br>Q: Medium A: High C: High | Low<br>Q: Medium A: Medium C: High |

Read *et al.* (1983) reported after the installation of a new sewage treatment works, which reduced the suspended solid content of liquid effluent by 60% in the Firth of Forth, *Saccharina latissima* became abundant where previously it had been absent. Bokn *et al.* (2003) conducted a nutrient loading experiment on intertidal fucoids. Within 3 years of the experiment no significant effect was observed in the communities, however, 4-5 years into the experiment a shift occurred from perennials to ephemeral algae. Although Bokn *et al.* (2003) focussed on fucoids the results could indicate that long-term (>4 years) nutrient loading can result in community shift to ephemeral algae species. Disparities between the findings of the aforementioned studies are likely to be related to the level of organic enrichment.

Johnston & Roberts (2009) conducted a meta-analysis, which reviewed 216 papers to assess how a variety of contaminants (including sewage and nutrient loading) affected 6 marine habitats (including subtidal reefs). A 30-50% reduction in species diversity and richness was identified from all habitats exposed to the contaminant types. Johnston & Roberts (2009) however also highlighted that macroalgal communities are relatively tolerant to contamination, but that contaminated communities can have low diversity assemblages which are dominated by opportunistic and fast growing species (Johnston & Roberts, 2009 and references therein). Organic enrichment may also result in phytoplankton blooms that increase turbidity and therefore may negatively impact photosynthesis.

**Sensitivity assessment.** Although short-term exposure (<4 years) to organic enrichment may not affect seaweeds directly, indirect effects such as turbidity may significantly affect photosynthesis, and result in reduced growth and reproduction and increased competition form fast growing but ephemeral species Resistance has been assessed as '**Medium**', resilience as '**High**'. Sensitivity has been assessed as '**Low**'.

## Physical Pressures

| | Resistance | Resilience | Sensitivity |
|---|---|---|---|
| **Physical loss (to land or freshwater habitat)** | None<br>Q: High A: High C: High | Very Low<br>Q: High A: High C: High | High<br>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.

| | Resistance | Resilience | Sensitivity |
|---|---|---|---|
| **Physical change (to another seabed type)** | None<br>Q: High A: High C: High | Very Low<br>Q: High A: High C: High | High<br>Q: High A: High C: High |

If sediment were replaced with rock or artificial substrata, this would represent a fundamental change to the biotope (Macleod *et al.*, 2014). All the characterizing species within this biotope can grow on rock biotopes (Birkett *et al.*, 1998; Connor *et al.*, 2004), however, SS.SMp.KSwSS are by definition sediment biotopes and introduction of rock would change them into a rock based habitat complex, and the biotope would be lost

**Sensitivity assessment.** Resistance to the pressure is considered '**None**', and resilience '**Very low**'. Sensitivity has been assessed as '**High**'

| | Resistance | Resilience | Sensitivity |
|---|---|---|---|
| **Physical change (to another sediment type)** | None<br>Q: Low A: NR C: NR | Very Low<br>Q: High A: High C: High | High<br>Q: Low A: Low C: Low |

SS.SMp.KSwSS are sediment based biotopes. Stabilised cobbles, pebbles, gravel and shell fractions provide a substrate for macro-algae to dominate the community (Connor *et al.*, 2004). An increase in the dominance of smaller sediment fractions e.g. sand and/or mud will likely smoother the existing biotope, inhibit successive re-colonisation of macroalgae and/or increase the sediment scour.

**Sensitivity assessment.** Resistance has been assessed as '**None**', resilience as **Very low** (the pressure is a permanent change), and sensitivity as **High.**

| | Resistance | Resilience | Sensitivity |
|---|---|---|---|
| **Habitat structure changes - removal of substratum (extraction)** | None<br>Q: Low A: NR C: NR | High<br>Q: High A: High C: High | Medium<br>Q: Low A: Low C: Low |

SS.SMp.KSwSS.SlatR (plus sub-biotopes), SS.SMp.KSwSS.SlatCho can be found on a varied mixture of sediment and rock fractions. Extraction of substratum to 30 cm is likely to remove small sediment fractions (e.g. gravel) and may mobilize the remaining larger rock fractions (e.g. boulders) causing high mortality within the resident community. All characterizing species have rapid growth rates and are likely to recover within 2 years.

**Sensitivity assessment.** Resistance has been assessed as '**None**', Resilience as '**High**'. Sensitivity has been assessed as '**Medium**'.

| | Resistance | Resilience | Sensitivity |
|---|---|---|---|
| **Abrasion/disturbance of the surface of the substratum or seabed** | None<br>Q: Low A: NR C: NR | Medium<br>Q: High A: High C: High | Medium<br>Q: Low A: Low C: Low |

Abrasion of the substratum e.g. from bottom or pot fishing gear, cable laying etc. may cause localised mobility of the substrata and mortality of the resident community. The effect would be situation dependent, however, if bottom fishing gear were towed over a site it may mobilise a high proportion of the rock substrata and cause high mortality in the resident community.

**Sensitivity assessment.** Resistance has been assessed as '**None**', Resilience as '**High**'. Sensitivity has been assessed as '**Medium**'.

| | | | |
|---|---|---|---|
| **Penetration or disturbance of the substratum subsurface** | None<br>Q: Low A: NR C: NR | High<br>Q: High A: High C: High | Medium<br>Q: Low A: Low C: Low |

Penetration and/or disturbance of the substrate below the surface of the seabed may cause localised mobility of the substrata and mortality of the resident community.

**Sensitivity assessment.** Resistance has been assessed as '**None**', Resilience as '**High**'. Sensitivity has been assessed as '**Medium**'.

| | | | |
|---|---|---|---|
| **Changes in suspended solids (water clarity)** | Low<br>Q: High A: High C: High | High<br>Q: High A: High C: High | Low<br>Q: High A: High C: High |

Suspended Particle Matter (SPM) concentration has a positive linear relationship with subsurface light attenuation (Kd) (Devlin *et al*., 2008). Light availability and water turbidity are principal factors in determining depth range at which macro-algae can be found (Birkett *et al*., 1998b). Light penetration influences the maximum depth at which laminarians can grow and it has been reported that laminarians grow at depths at which the light levels are reduced to 1 percent of incident light at the surface. Maximal depth distribution of laminarians, therefore, varies from 100 m in the Mediterranean to only 6-7m in the silt-laden German Bight. In Atlantic European waters, the depth limit is typically 35 m. In very turbid waters the depth at which kelp is found may be reduced, or in some cases excluded completely (e.g. Severn Estuary), because of the alteration in light attenuation by suspended sediment (Lüning, 1990; Birkett *et al.* 1998b). Laminarians show a decrease of 50% photosynthetic activity when turbidity increases by 0.1/m (light attenuation coefficient =0.1-0.2/m; Staehr & Wernberg, 2009).

**Sensitivity Assessment.** A decrease in turbidity is likely to support enhanced growth (and possible habitat expansion) and is therefore not considered in this assessment. An increase in water turbidity is likely to primarily affect photosynthesis, therefore, growth and density of the canopy forming seaweeds. Resistance to this pressure is defined as '**Low**' and resilience to this pressure is defined as '**High**' at the benchmark level due to the scale of the impact. Hence, this biotope is regarded as having a sensitivity of '**Low**'.

| | | | |
|---|---|---|---|
| **Smothering and siltation rate changes (light)** | High<br>Q: Low A: NR C: NR | High<br>Q: High A: High C: High | Not sensitive<br>Q: Low A: Low C: Low |

Smothering by sediment e.g. 5 cm material during a discrete event, is unlikely to damage mature examples of *Saccharina latissima* and *Chorda filum* but may provide a physical barrier to zoospore settlement and therefore could negatively impact on recruitment processes (Moy & Christie, 2012). Laboratory studies showed that kelp and gametophytes can survive in darkness for between 6-16 months at 8 °C and would probably survive smothering by a discrete event and once returned to normal conditions gametophytes resumed growth or maturation within 1 month

(Dieck, 1993).

SS.SMp.KSwSS biotopes are all recorded in moderately strong tidal streams to negligible (≤1.5 m/sec) (Connor *et al*., 2004). In tidally exposed biotopes deposited sediment is unlikely to remain for more than a few tidal cycles (due to water flow or wave action). In sheltered biotopes deposited sediment could remain however are unlikely to remain for longer than a year.

**Sensitivity assessment.** Resistance has been assessed as '**High**', resilience as '**High**'. Sensitivity has been assessed as '**Not Sensitive**'.

| | | | |
|---|---|---|---|
| **Smothering and siltation rate changes (heavy)** | Medium<br>Q: Low A: NR C: NR | High<br>Q: Low A: NR C: NR | Low<br>Q: Low A: NR C: NR |

Smothering by sediment e.g. 30 cm material during a discrete event, is unlikely to damage mature examples of Saccharina latissima and *Chorda filum* but may provide a physical barrier to zoospore settlement and therefore could negatively impact on recruitment processes (Moy & Christie, 2012). Laboratory studies showed that kelp and gametophytes can survive in darkness for between 6-16 months at 8°C and would probably survive smothering by a discrete event and once returned to normal conditions gametophytes resumed growth or maturation within 1 month (Dieck, 1993).

SS.SMp.KSwSS biotopes are all recorded in moderately strong tidal streams to negligible (≤1.5 m/sec) (Connor *et al*., 2004). In tidally exposed biotopes deposited sediment is unlikely to remain for more than a few tidal cycles (due to water flow or wave action). In sheltered biotopes deposited sediment could remain however are unlikely to remain for longer than a year.

**Sensitivity assessment.** Resistance has been assessed as '**Medium**', resilience as '**High**'. Sensitivity has been assessed as '**Low**'.

| | | | |
|---|---|---|---|
| **Litter** | Not Assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR | Not assessed (NA)<br>Q: NR A: NR C: NR |

**Not assessed.**

| | | | |
|---|---|---|---|
| **Electromagnetic changes** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | No evidence (NEv)<br>Q: NR A: NR C: NR |

No evidence

| | | | |
|---|---|---|---|
| **Underwater noise changes** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

Not relevant

| | | | |
|---|---|---|---|
| **Introduction of light or shading** | Low<br>Q: Low A: NR C: NR | Medium<br>Q: Low A: NR C: NR | Medium<br>Q: Low A: Low C: Low |

There is no evidence to suggest that anthropogenic light sources would affect macro-algae. Shading of the biotope (e.g. by the construction of a pontoon, pier etc.) could adversely affect the biotope in areas where the water clarity is also low, and tip the balance to shade tolerant species, resulting in the loss of the biotope directly within the shaded area, or a reduction in seaweed abundance.

**Sensitivity assessment.** Resistance is probably '**Low**', with a '**Medium**' resilience and a sensitivity of '**Medium**', albeit with 'low' confidence due to the lack of direct evidence.

| | | | |
|---|---|---|---|
| **Barrier to species movement** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

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

| | | | |
|---|---|---|---|
| **Death or injury by collision** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

**Not relevant.** Collision from grounding vessels is addressed under abrasion above.

| | | | |
|---|---|---|---|
| **Visual disturbance** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

Not relevant

## Biological Pressures

| | Resistance | Resilience | Sensitivity |
|---|---|---|---|
| **Genetic modification & translocation of indigenous species** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | No evidence (NEv)<br>Q: NR A: NR C: NR |

At the time of writing there is **no evidence** for translocation of *Saccharina latissima*, *Chorda filum* over significant geographic distances.

| | | | |
|---|---|---|---|
| **Introduction or spread of invasive non-indigenous species** | None<br>Q: High A: High C: High | Very Low<br>Q: High A: High C: High | High<br>Q: High A: High C: High |

*Undaria pinnatifida* has received a large amount of research attention as a major Invasive Non-Indigenous Species (INIS) which could out-compete native UK kelp habitats (see Farrell & Fletcher, 2006; Thompson & Schiel, 2012, Brodie *et al.*, 2014; Hieser *et al.*, 2014). *Undaria pinnatifida* was first recorded in the UK, Hamble Estuary, in June 1994 (Fletcher & Manfredi, 1995) and has since spread to a number of British ports. *Undaria pinnatifida* is an annual species, sporophytes appear in Autumn and grow rapidly throughout winter and spring during which they can reach a length of 1.65m (Birket *et al.*, 1998). Farrell & Fletcher (2006) suggested that native short-lived species that occupy similar ecological niches to *Undaria pinnatifida*, such as *Saccharina latissima* or *Chorda filum*, are likely to be worst affected and out-competed by *Undaria pinnatifida*. Where present, an abundance of *Undaria pinnatifida* has corresponded to a decline in *Saccharina lattisima* (Farrel & Fletcher, 2006) and *Laminaria hyperborea* (Hieser *et al*., 2014).

In New Zealand, Thompson & Schiel (2012) observed that native fucoids could out-compete *Undaria pinnatifida* and re-dominate the substratum. However, Thompson & Schiel (2012) suggested the fucoid recovery was partially due to an annual *Undaria pinnatifida* die back, which as noted by Heiser *et al*., (2014) does not occur in Plymouth sound, UK. *Undaria pinnatifida* was successfully eradicated on a sunken ship in Clatham Islands, New Zealand, by applying a heat treatment of 70 °C (Wotton *et al*., 2004) however numerous other eradication attempts have failed, and as noted by Fletcher & Farrell, (1999) once established *Undaria pinnatifida* resists most attempts of long-term removal. The biotope is unlikely to fully recover until *Undaria pinnatifida* is fully removed from the habitat, which as stated above is unlikely to occur.

**Sensitivity assessment.** Resistance to the pressure is considered '**Low**', and resilience '**Very low**'. The sensitivity of this biotope to the introduction of microbial pathogens is assessed as '**High**'.

| | | | |
|---|---|---|---|
| **Introduction of microbial pathogens** | Low<br>Q: Low A: NR C: NR | High<br>Q: High A: Low C: High | Low<br>Q: Low A: Low C: Low |

*Laminarians* may be infected by the microscopic brown alga *Streblonema aecidioides*. Infected algae show symptoms of Streblonema disease, i.e. alterations of the blade and stipe ranging from dark spots to heavy deformations and completely crippled thalli Infection can reduce growth rates of host algae (Peters & Scaffelke, 1996). The marine fungi *Eurychasma spp* can also infect early life stages of laminarians, however, the effects of infection are unknown (Müller *et al*., 1999).

**Sensitivity assessment.** Resistance to the pressure is considered '**Low**', and resilience '**High**'. The sensitivity of this biotope to the introduction of microbial pathogens is assessed as '**Low**'.

| | | | |
|---|---|---|---|
| **Removal of target species** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

This pressure has been assessed as '**Not relevant'.**

There has been recent commercial interest in *Saccharina lattissima* as a consumable called "sea vegetables" (Birket *et al*., 1998). However, *Saccharina lattissima* sporophytes are typically matured on ropes (Handå et al 2013) and not directly extracted from the seabed, as with *Laminaria hyperborea* (Christie *et al*., 1998). No evidence has been found for commercial extraction of *Chorda filum*.

| | | | |
|---|---|---|---|
| **Removal of non-target species** | None<br>Q: Low A: NR C: NR | High<br>Q: High A: High C: High | Medium<br>Q: Low A: Low C: Low |

Low level disturbances (e.g. solitary anchors) are unlikely to cause harm to the biotope as a whole, due to the impact's small footprint. Thus, evidence to assess the resistance of SS.SMp.KSwSS.SlatR (plus sub-biotopes), SS.SMp.KSwSS.SlatCho to non-targeted removal is limited. It is assumed that incidental non-targeted catch (e.g. by trawls or dredges) could mobilise sediment, remove large kelp species, overturn boulders and cobbles and bury smaller seaweeds and cause high mortality within the affected area.

**Sensitivity assessment.** Resistance has been assessed as '**None**', Resilience as '**High**'. Sensitivity has been assessed as '**Medium**'.

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