Saccharina latissima, *Chorda filum* and dense red seaweeds on shallow unstable infralittoral boulders or cobbles

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Marine Evidence–based Sensitivity Assessment (MarESA) Review

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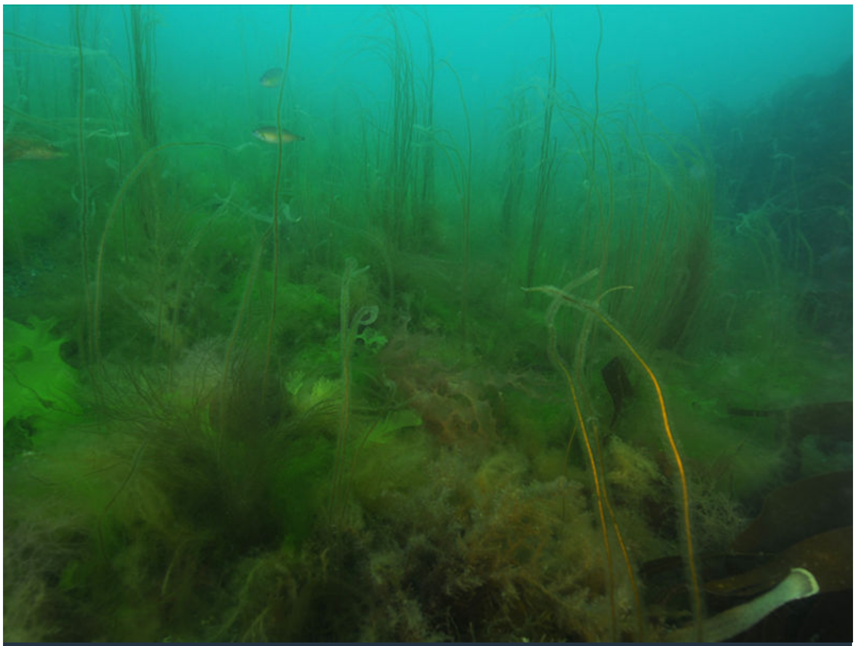

***Saccharina latissima*, *Chorda filum* and dense red seaweeds on shallow unstable infralittoral boulders or cobbles**
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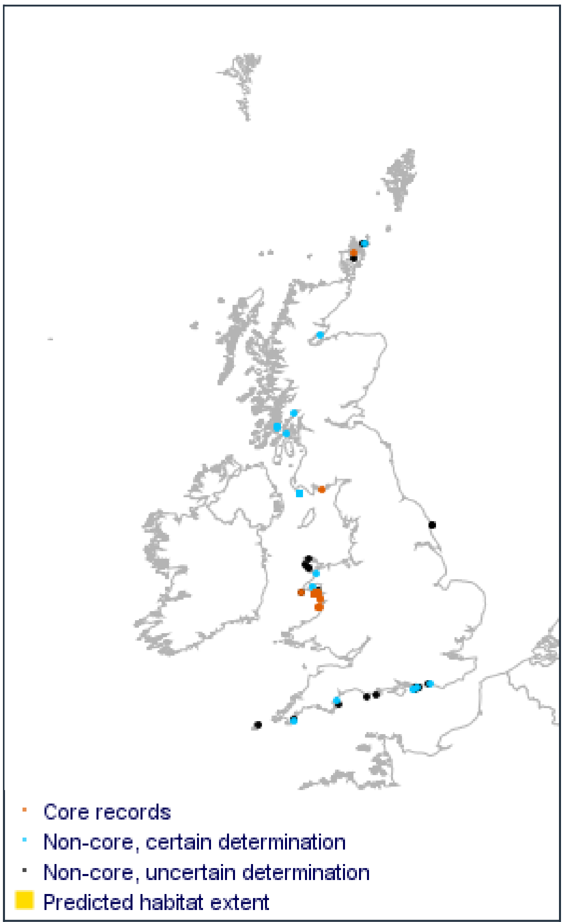

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Dr Keith Hiscock **Refereed by** This information is not refereed.

Summary

UK and Ireland classification

EUNIS 2008	A3.123	*Laminaria saccharina*, *Chorda filum* and dense red seaweeds on shallow unstable infralittoral boulders and cobbles
JNCC 2015	IR.HIR.KSed.SlatChoR	*Saccharina latissima*, *Chorda filum* and dense red seaweeds on shallow unstable infralittoral boulders or cobbles
JNCC 2004	IR.HIR.KSed.LsacChoR	*Laminaria saccharina*, *Chorda filum* and dense red seaweeds on shallow unstable infralittoral boulders or cobbles
1997 Biotope	IR.MIR.SedK.LsacChoR	*Laminaria saccharina*, *Chorda filum* and dense red seaweeds on shallow unstable infralittoral boulders and cobbles

Description

Unstable boulders and cobbles in very shallow water may be seasonally disturbed which prevents a stable *Laminaria hyperborea* forest from developing. Seasonal movement of the substratum results in a community of the opportunistic kelp *Saccharina latissima*, *Chorda filum* and *Desmarestia* spp. with encrusting algae and sediment-tolerant seaweeds. The shallowest areas of the Sarns in Cardigan Bay are typical examples of this biotope. (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

Depth range

0-5 m

Additional information

-

Listed By

- none -

Further information sources

Search on:

G G G JNCC

Habitat review

Ecology

Ecological and functional relationships

The species present in this biotope thrive particularly in conditions of disturbance. They are mainly annual species with rapid growth or are perennial species that may die back in winter and persist as crusts or basal portions that survive abrasion during winter storms. Grazing species such as sea urchins do not survive well in conditions of abrasion and so seaweeds can thrive.

Seasonal and longer term change

It is expected that there will be considerable reduction in the abundance of foliose seaweeds especially following the summer. The reduction is partly because of grazing, partly seasonal disintegration of fronds and partly abrasion. Annual seaweeds start to colonize and perennial seaweeds to regrow in about April and can be expected to be fully grown by May.

Habitat structure and complexity

This is a complex habitat with semi-stable hard substratum supporting epibiota through to sediments supporting infauna. The fronds of seaweeds also provide significant surfaces especially for epibiota and for gastropods. The holdfasts of *Saccharina latissima* and, where present, of *Saccorhiza polyschides* provide a habitat for cryptic animal species.

Productivity

This biotope would appear to be productive of organic matter from seaweeds especially.

Recruitment processes

The dominant and characteristic species are recruited from planktonic larvae and spores. Other species such as fish and crustaceans are mainly transitory once settled.

Time for community to reach maturity

Providing that sources of larvae, spores and mobile animals are nearby, the biotope would develop rapidly on new substrata so that, in appearance based on visually dominant species, it would be likely to be established in a year. However, recruitment of a full range of species, especially molluscs and some algae would take longer so that a dynamic stability would probably be reached only after about three years.

Additional information

No information was available on the infauna associated with this biotope although it is expected that species will be tolerant of displacement.

Preferences & Distribution

Habitat preferences

Depth Range	0-5 m
Water clarity preferences	
Limiting Nutrients	No information found
Salinity preferences	Full (30-40 psu)
Physiographic preferences	Open coast
Biological zone preferences	Upper infralittoral
Substratum/habitat preferences	Large to very large boulders, Small boulders, Cobbles, Pebbles, Gravel / shingle
Tidal strength preferences	Moderately Strong 1 to 3 knots (0.5-1.5 m/sec.)
Wave exposure preferences	Moderately exposed
Other preferences	

Additional Information

See Sanderson *et al.* (2001) for detailed descriptions of the biotope

Species composition

Species found especially in this biotope

Rare or scarce species associated with this biotope

-

Additional information

The biotope may be conspicuously characterized by dense red algae (often bleached by sunlight) in spring and summer. These algae are ephemeral and especially include *Cystoclonium purpureum* and *Brongniartella byssoides* as well as the brown alga *Desmarestia aculeata*.

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

IR.HIR.KSed.SlatChoR is within the sediment affected or disturbed kelp and seaweed communities (IR.HIR.KSed) habitat complex. Shallow boulders and cobbles are seasonally mobilised and the opportunistic brown seaweeds; *Saccharina latissima* (formerly *Laminaria saccharina*) and *Chorda filum* proliferate. The seasonal mobility of the substrata dislodges the resident community and inhibits the establishment of *Laminaria hyperborea* biotopes. As stability increases *Laminaria hyperborea* can become more abundant (Connor *et al.*, 2004).

Due to the disturbed nature of IR.HIR.KSed biotopes the understory community can be locally variable and defined by scour tolerant or ephemeral seaweeds, such as; Brown filamentous seaweeds (Ectocarpales), *Chondrus crispus*, *Corallina officinalis*, *Dilsea carnosa*, encrusting coralline algae and *Phyllophoras pseudoceranoides*. Faunal diversity and abundance are also generally low and typically limited to; encrusting bryozoans, *Spirobranchus triqueter* and other scour tolerant fauna (Connor *et al.*, 2004).

In undertaking this assessment of sensitivity, an account is taken of knowledge of the biology of all characterizing species/taxa in the biotope. However, 'indicative species' are particularly important in undertaking the assessment because they have been subject to detailed research. For this sensitivity assessment the opportunistic brown seaweeds; *Saccharina latissima* & *Chorda filum* are the primary foci of research. Examples of other important species groups are mentioned where appropriate.

Resilience and recovery rates of habitat

Saccharina latissima (formerly *Laminaria saccharina*) and *Chorda filum* are opportunistic seaweeds which have relatively fast growth rates when compared to other perennial species, and can dominate in areas subject to recurrent disturbance. *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). *Saccharina lattisma* is widely distributed in the north Atlantic from Svalbard to Portugal (Birket *et al.*, 1998; Conor *et al.*, 2004; Bekby & Moy 2011; Moy & Christie 2012). *Chorda filum* has a widely distributed across the northern hemisphere (Algae Base, 2015). In the North Atlantic specifically, *Chorda filum* is recorded from Svalbard (Fredriksen *et al.*, 2014) to Northern Portugal (Araújo *et al*, 2009). *Chorda filum* is an annual seaweed, completing it's life cycle in a single season (Novaczek *et al.*, 1986).

Saccharina lattisma and *Chorda filum* have heteromorphic life strategies (Bikett *et al.*, 1988). 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. *Laminariale* 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 3m (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 ≥2.25m per year (Birket *et al*., 1998). *Chorda filum* recruits appear from February (South & Burrows, 1967), beyond which is a period of rapid growth during which sporophytes can reach a length of ≤6m (South & Burrows, 1967). In culture *Chorda fillum* can reach reproductive maturity and produce zoospores within 186 days (ca 6 months) of settlement, however, 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, Leinaas & Christie (1996) removed Strongylocentrotus droebachiensis from "Urchin Barrens" and observed a succession effect. Initially, the substratm was colonized by filamentous algae, after a couple of weeks these were out-competed and the habitat dominated by *Saccharina latissima*, 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, however 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, 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* and *Chorda filum* are opportunistic species with rapid colonization and growth rates (South & Burrows, 1967; Birket *et al*., 1998). *Chorda filum* is an annual seaweed, completing it's life cycle within a single season. *Saccharina latissima* has been shown to be an early colonizer within algal succession, appearing within 2 weeks of clearance. Resilience has therefore been assessed as '**High'** for all levels of resistance.

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	None Q: High A: High C: High	High Q: High A: High C: High	Medium 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.

IR.HIR.KSed.Slat.ChoR is distributed throughout the UK (Connor *et al.*, 2004). 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 lattisma* 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 lattisma* and inhibit *Chorda filum* reproduction. Resistance has been assessed as '**None**', Resilience as '**High**'. Sensitivity has been assessed as '**Medium**'.

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

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 suggests 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 Q: Low A: NR C: NR	High Q: High A: High C: High	Low Q: Low A: Low C: Low

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‰ long-term 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 Q: High A: High C: High	High Q: High A: High C: High	Low 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 affect of long-term salinity changes (>5 days) or salinity >60 PSU on *Saccharina latissima'* photosynthetic ability was not tested. 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 and quicker.

Chorda filum is tolerant of low salinities (Hayren, I940; Norton & South, 1969), and has been recorded at Björnholm, Finland where salinity has been recorded as low as 5.15%o (Hayren, I940). Norton & South (1969) observed (experimentally) that *Chorda filum* could develop sporophytes at ≥5%o, however at low salinities the time taken to develop into sporophytes was slower than at full salinities (5%o=65 days, 35%o=16 days) and below 9% sporophytes did not grow above 2mm in length.

Sensitivity assessment. A decrease in one MNCR salinity scale from "Full Salinity" (30-40psu) to "Reduced Salinity" (18-30 psu) may inhibit *Saccharina lattissima* photosynthesis and hence growth. *Chorda filum* is highly tolerant of low salinity and is unlikely to be affected. Resistance has been assessed as '**Medium**' resilience as '**High**'. Sensitivity of this biotope to a decrease in salinity has been assessed as '**Low**'.

Water flow (tidal current) changes (local)	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive 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.

Sensitivity assessment. IR.HIR.KSed.SlatChoR is recorded from moderately strong (0.5-1.5m/sec)-weak tidal streams (<0.5m/sec).A change of 0.1m/s to 0.2m/s is not likely to dramatically affect biotope structure. Resistance has been assessed as '**High**', resilience as '**High**'. Sensitivity has been assessed as '**Not Sensitive**'.

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

IR.HIR.KSed.SlatChoR is recorded from 0-10m Below Chart Datum (BCD) (Connor *et al.*, 2004). Both *Saccharina latissima* and *Chorda filum* can grow in the sub-littoral fringe (South & Burrows, 1967) and as such would likely 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 canopy forming seaweeds has also been shown to increase desiccation and mortality of the understory macro-algae (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 Q: Medium A: High C: High	High Q: High A: High C: High	Not sensitive Q: Medium A: High C: High

IR.HIR.KSed.SlatChoR is recorded from extreme wave exposed-sheltered sites (Connor *et al.*, 2004). Birket *et al.*, (1998) suggested that *Saccharina latissima* is rarely present in areas of wave exposure, where it is out-competed by *Laminaria hyperborea*. However, the seasonal unstable nature of the substrata within IR.HIR.KSed.SlatChoR is likely to inhibit growth of *Laminaria hyperborea* and allow *Saccharina latissima* to opportunistically colonize rock particles. *Chorda filum* sporophytes often grow on unstable objects, such as pebbles and shell. Owing to typically unstable substrate 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.

Sensitivity assessment. A large scale increase in local wave height may increase local sediment mobility, potentially increase dislodgment or relocation of sporophytes (South & Burrows, 1967; Birket *et al.*, 1998). 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) 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

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) 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.

The mucilaginous slime layer coating of laminariales 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 1-22.5m 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) 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

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 antifouing 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	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: Medium A: High C: High	High Q: High A: High C: High	Not sensitive Q: High 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) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not sensitive 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 when compared to other sites along the east coast of Scotland. At St Andrews, nitrate levels were 20.22μM, which represents an approx 25% increase when compared to other comparable 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 Salmon farms, where elevated ammonium can be readily absorbed. 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 occurred. 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, however, could also be time dependant.

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).

At the time of writing little direct evidence for the effects of nutrient enrichment on *Chorda filum* could be found. Bonsdorff *et al.*, (2002) noted that chronic eutrophication in coastal areas can cause an increased abundance and dominance of filamentous algae, resulting in a decline of other resident algal communities. For example in Puck Bay, Poland *Chorda filum*, *Fucus vesiculosus* and *Furcellaria*

Lumbricalis have been absent sine the 1970's and the filamentous species *Ectocarpus spp.* and *Pilayella spp.* now dominates the area (Ciszewski *et al.*, 1992).

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 from 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 Q: Medium A: High C: High	High Q: High A: Medium C: High	Low Q: Medium A: Medium C: High

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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. 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 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

If rock substrata were replaced with sedimentary substrata this would represent a fundamental change in habitat type, which *Saccharina latissima* and *Chorda filum* would not be able to tolerate. The biotope would be lost.

Sensitivity assessment. Resistance to the pressure is considered '**None**', and resilience '**Very Low**' or 'None'. The sensitivity of this biotope to change from sedimentary or soft rock substrata to hard rock or artificial substrata or vice-versa is assessed as '**High**'.

Physical change (to another sediment type)	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant on hard rock substrata

Habitat structure changes - removal of substratum (extraction)	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant on hard rock substrata

Abrasion/disturbance of the surface of the substratum or seabed	None Q: Low A: NR C: NR	High Q: High A: High C: High	Medium 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	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, please refer to pressure "Abrasion/disturbance of the substrata on the surface of the seabed".

Changes in suspended solids (water clarity)	None Q: High A: High C: High	Medium Q: High A: Medium C: High	Medium 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 6-7 m 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. An increase in water clarity from clear to intermediate (10-100mg/l) represent a change in light attenuation of ca 0.67-6.7 Kd/m, and is likely to result in a greater than 50% reduction in photosynthesis of *Laminaria* spp. Therefore, the dominant kelp species will probably suffer a severe decline and resistance to this pressure is assessed as '**None**'. Resilience is probably to this pressure is defined as '**Medium**' at the benchmark. Hence, this biotope is regarded as having a sensitivity of '**Medium** 'to this pressure.

Smothering and siltation rate changes (light)	High Q: Low A: NR C: NR	High Q: Low A: NR C: NR	Not sensitive Q: Low A: NR C: NR

Smothering by sediment e.g. 5 cm material during a discrete event, is unlikely to damage *Saccharina latissima* and *Chorda filum* sporophytes 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).

IR.HIR.KSed.SlatChoR is recorded from extreme wave exposed-sheltered sites (Connor *et al.*, 2004). In wave 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 Q: Low A: NR C: NR	High Q: Low A: NR C: NR	Low Q: Low A: Low C: Low

Smothering by sediment e.g. 30 cm material during a discrete event, is unlikely to damage mature *Saccharina latissima* and *Chorda filum* sporophytes but may provide a physical barrier to zoospore settlement and, therefore, could negatively impact on recruitment processes (Moy & Christie, 2012). The volume of sediment may also inundate juvenile sporophytes. Given the microscopic size of the gametophyte, 30cm of sediment could be expected to significantly inhibit growth. 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).

IR.HIR.KSed.SlatChoR is recorded from extreme wave exposed-sheltered sites (Connor *et al.*, 2004). In wave 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, is 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) 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	Not relevant (NR) 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

Not relevant

Introduction of light or shading	Low Q: Low A: NR C: NR	Medium Q: Low A: NR C: NR	Medium Q: Low A: Low C: Low

There is no evidence to suggest that anthropogenic light sources would affect *Saccharina latissima* or *Chorda filum*. 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) 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 the dispersal of spores, but spore 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.

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	No evidence (NEv) Q: NR A: NR C: NR

There is little evidence for translocation of *Saccharina latissima* or *Chorda filum* over significant geographic distances. Nor is there any evidence regarding the genetic modification or effects of translocation of native kelp populations.

Introduction or spread of invasive non-indigenous species	Low Q: High A: High C: High	Very Low Q: High A: High C: High	High 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 (Birkett *et al.*, 1998b). 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* 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 *U.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 pinadifida* 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 Q: Low A: NR C: NR	High Q: High A: High C: High	Low Q: Low A: Low C: Low

Laminariales 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 Laminariales and *Desmarestia viridis*, 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) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

There has been recent commercial interest in *Saccharina lattisima* 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*. This pressure has therefore been assessed as **not relevant.**

Removal of non-target species	None Q: Low A: NR C: NR	High Q: High A: High C: High	Medium Q: Low A: Low C: Low

Low level disturbances (e.g. solitary anchors and scallop dredges) 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 IR.HIR.KSed.SlatChoR to non-targeted removal is limited. It is assumed that incidental non-targeted catch will mobilise sediment and cause high mortality within the affected area.

Sensitivity assessment. Resistance has been assessed as '**None**', resilience as '**High**', and sensitivity assessed as '**Medium**'.

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