Saccharina latissima with foliose red seaweeds and ascidians on sheltered tide-swept infralittoral rock

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Marine Evidence–based Sensitivity Assessment (MarESA) Review

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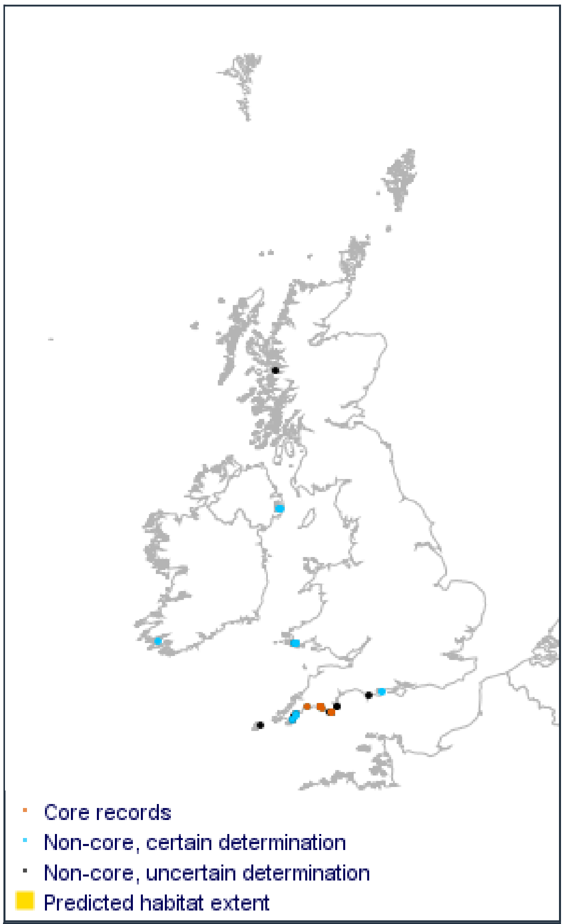

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Thomas Stamp **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A3.224	*Laminaria saccharina* with foliose red seaweeds and ascidians on sheltered tide-swept infralittoral rock
JNCC 2015	IR.MIR.KT.SlatT	*Saccharina latissima* with foliose red seaweeds and ascidians on sheltered tide-swept infralittoral rock
JNCC 2004	IR.MIR.KT.LsacT	*Laminaria saccharina* with foliose red seaweeds and ascidians on sheltered tide-swept infralittoral rock
1997 Biotope		

Description

Sheltered, tide-swept rock in south-western Britain tends to be restricted to estuarine conditions, where variable salinity and increased turbidity have a significant effect on the biota. Due to the turbidity of the water, the infralittoral zone is restricted to very shallow depths. Unlike the tide-swept channels in sealochs, which support a mixed kelp canopy, the rock in these estuaries is characterized by *Saccharina latissima* alone, occurring in relatively low abundance (Frequent). The brown alga *Desmarestia ligulata* can occur in this biotope, though never dense, along with the non-native brown seaweed *Sargassum muticum*. Beneath the sparse kelp, cobbles and boulders, often surrounded by sediment, are encrusted by fauna and often a dense turf of red seaweed. The foliose red seaweeds associated with this biotope include *Callophyllis laciniata*, *Nitophyllum punctatum*, *Kallymenia reniformis*, *Gracilaria gracilis*, *Gymnogongrus crenulatus*, *Hypoglossum hypoglossoides*, *Rhodophyllis divaricata*, *Chylocladia verticillata*, *Cryptopleura ramosa* and *Erythroglossum laciniatum* as well as the filamentous *Ceramium nodulosum* and *Pterothamnion plumula*. Green seaweeds *Ulva lactuca*, *Bryopsis plumosa* and *Cladophora* spp. may be locally abundant. The dominating faunal species vary from site to site but include sponges such as *Halichondria panicea*, *Esperiopsis fucorum*, *Dysidea fragilis* and *Hymeniacidon perleve* as well as ascidians, particularly *Dendrodoa grossularia* and *Morchellium argus*, which can cover the rocks. Also present is the anthozoan *Anemonia viridis*, the barnacle *Balanus crenatus* and the tube-building polychaete *Spirobranchus triqueter*. The hydroid *Plumularia setacea* can cover rocks and seaweed fronds Of the range of solitary ascidians found in the north-west, only *Ascidiella aspersa* tends also to be present in these south-western inlets. There is also a general absence of echinoderms. Where there is vertical rock present, it tends to support more fauna, including barnacles *Balanus crenatus*, the ascidians *Clavelina lepadiformis* and *Botryllus schlosseri* and sometines the featherstar *Antedon bifida*. Where soft rock allows, such as the limestone in Plymouth Sound, rock-boring organisms such as *Polydora* sp. may be locally abundant. Sheltered, tide-swept rock is generally restricted to the narrows or tidal rapids of marine inlets. The clear tide-swept waters of Scottish sealochs are significantly different to the marine inlets of south-west Britain. This biotope deals with the latter. (Information from Connor *et al*., 2004; JNCC, 2105).

Depth range

-

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

IR.MIR.KT.SlatT is typically restricted to estuarine environments, in which strong tidal streams, variable salinity and high turbidity influence the community. Beneath a sparse *Saccharina latissima* (syn. *Laminaria saccharina*) canopy is a community of encrusting fauna and a dense turf of red seaweeds. Ascidians can also be a dominant component of the understory, notably *Dendrodoa grossularia* and *Morchellium argus* which can cover rock surfaces.

In undertaking this assessment of sensitivity, account is taken of knowledge of the biology of all characterizing species in the biotope. At the time of writing limited evidence could be found for *Morchellium argus*. Hawkins & Harkin (1985) also demonstrated that if the canopy forming kelps are removed the understory red seaweed communities are likely to perish. It was therefore deemed that the red seaweed community of IR.MIR.KT.SlatT was dependent on the presence of *Saccharina latissima*. *Saccharina latissima* and *Dendrodoa grossularia* are therefore the primary foci of research, however examples of important species groups are mentioned where appropriate.

Resilience and recovery rates of habitat

Saccharina lattisma is a perennial kelp characteristic of wave sheltered sites of the North East Atlantic, distributed from northern Portugal to Spitzbergen, Svalbard (Birkett *et al.*, 1998; Conor *et al.*, 2004; Bekby & Moy, 2011; Moy & Christie, 2012). *Saccharina lattisma* is capable of reaching maturity within 15-20 months (Sjøtun, 1993) and has a life expectancy of 2-4 years (Parke, 1948). Maximum growth has been recorded in late winter early spring, in late summer and autumn growth rates slow (Parke, 1948; Lüning, 1979; Birkett *et al.*, 1998). The overall length of the sporophyte may not change during the growth season due to marginal (distal) erosion of the blade but extension growth of the blade has been measured at 1.1 cm/day, with total length addition of over 2.25m of tissue per year (Birkett *et al.*, 1998). *Saccharina latissima* has a heteromorphic life strategy. Vast numbers of zoospores are released from sori located centrally on the blade between autumn and winter. Zoospores settle onto rock substrata and develop into dioecious gametophytes (Kain, 1979) which, following fertilization, germinate into juvenile sporophytes from winter-spring. Kelp 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 following disturbance can be influenced by the proximity of mature kelp beds producing viable zoospores to the disturbed area (Kain, 1979; Fredriksen *et al.*, 1995).

The temperature isotherm of 19-20°C has been reported as limiting *Saccharina lattisma* growth (Müller *et al.*, 2009). Gametophytes can develop in ≤23°C (Lüning, 1990). However, Bolton & Lüning (1982) reported an experimental optimal temperature of 10-15°C for growth of the *Saccharina latissima* sporophyte. Growth was inhibited by 50-70% at 20°C and, all experimental specimens completely disintegrated after 7 days at 23°C.. In the field, *Saccharina latissima* has, however, shown significant regional variation in its acclimation response to changing environmental conditions. For example, Gerard & Dubois (1988) observed sporophytes of *Saccharina latissima* which were regularly exposed to ≥20°C could tolerate these high 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 2002 a large scale decline of *Saccharina latissima* was discovered on the Norwegian coast (Moy & Christie, 2012). A subsequent large survey was undertaken between 2004-2009 of 660 sites covering 34,000 km of south and west Norway to assess the decline of *Saccharina latissima* abundance and distribution (Moy & Christie, 2012). The survey indicated an 83% reduction of *Saccharina latissima* forests across the south Norwegian region of Skagerrak. The west Norwegian coast was less affected, but *Saccharina latissima* was either absent or very sparse at 38% of sites where it was expected to be abundant. At all sites where *Saccharina latissima* was sparse a community of ephemeral macro-algae species was dominant and persisted throughout the study period (2004-2009). Bekby & Moy (2011) modelled the regional decline which indicated a decline of 50.7% of *Saccharina latissima* from Skagerrak, Norway. Approximately 50% of Europe's *Saccharina latissima* is found in Norway (Moy *et al*., 2006), therefore, despite large discrepancies between the two estimates of *Saccharina latissima* decline (50.7-83%) the results indicated a significant decline in *Saccharina latissima* across the region. Moy & Christie (2012) suggested the ephemeral filamentous macroalgae communities represented a stable state shift that had persisted throughout the study period (2004-2009). Although no measurements were made, they suggested that the decline was due to low tidal movement and wave action in the worst affected areas combined with the impacts of dense human populations and increased land run-off multiple stressors such as eutrophication, increasing regional temperature, increased siltation and overfishing may also be acting synergistically to cause the observed habitat shift.

Other factors that are likely to influence the recovery of kelp biotopes is competitive interactions with the Invasive Non Indigenous Species (INIS) *Undaria pinnatifida* (Smale *et al*., 2013; Brodie *et al*., 2014; Heiser 2014). *Undaria pinnatifida* has received a large amount of research attention as an INIS which could out-compete UK kelp habitats (see Farrell & Fletcher, 2006; Thompson & Schiel, 2012, Brodie *et al*., 2014; Hieser *et al*., 2014). *Undaria pinnatifida* was first recorded in Plymouth Sound, UK in 2003 (NBN, 2015) subsequent surveys in 2011 have reported that *Undaria pinnatifida* is widespread throughout Plymouth Sound, colonizing rocky reef habitats. Where *Undaria pinnatifida* is present there was a significant decrease in the abundance of other *Laminaria* species, including *Laminaria hyperborea* (Heiser *et al*., 2014). In New Zealand, Thompson & Schiel (2012) observed that native fucoids could out-compete *Undaria pinnatifida* and redominate the substratum. However, Thompson & Schiel (2012) suggested the fucoid recovery of the substratum was partially due to an annual *Undaria pinnatifida* die back, which as noted by Heiser *et al*. (2014) did not occur in Plymouth sound, UK. It is unknown whether *Undaria pinnatifida* will out-compete native macro-algae in the UK. However from 2003-2011 *Undaria pinnatifida* had spread throughout Plymouth sound, UK, becoming a visually dominant species at some locations within summer months (Hieser *et al*., 2014). At the time of writing there is limited evidence available to assess the ecological impacts of *Undaria pinnatifida* on *Laminaria hyperborea* associated communities. Kelp biotopes are unlikely to fully recover until *Undaria pinnatifida* is fully removed from the habitat, which as stated above is unlikely to occur.

Dendrodoa grossularia is a small solitary ascidian (1.5-2 cm diameter (Miller, 1954)) which is distributed throughout the Arctic ocean to its southern range edge in the British Isles (WORMS, 2015). *Dendrodoa grossularia* is described as a social ascidian which can live as an individual or in large aggregations of 200+ individuals (MarLIN, 2015). Settlement occurs from April-June, by the following summer individuals reach their maximum size. Life expectancy is expected to be 18-24months. Sexual maturity is reached within the second year of growth and the release of gametes occurs from spring-autumn, with peaks in early spring and another in late summer. Gamete release is reduced at temperatures above 15°C and totally suppressed above ca. 20°C (Miller, 1954). *Dendrodoa grossularia* has been recorded as an abundant component of benthic fauna in Nottinghambukta, Svalbard where annual temperature can range from 3-5 °C

(Beszczynska-Möller & Dye, 2013) and salinity between 6 and 20‰ (Różycki & Gruszczyński, 1991). At the time of writing no information could be found on the upper temperature threshold of mature *Dendrodoa grossularia* or hyper salinity tolerances. Kenny & Rees (1994) observed *Dendrodoa grossularia* was able to recolonize rapidly following aggregate dredging. Following experimental dredging of a site off the English coast, which extracted an area of 1-2m wide and 0.3-0.5m deep, *Dendrodoa grossularia* was able to recolonize and attained 40% of pre-dredge abundance and 23% of biomass within 8 months. This recover rate combined with the ability of this species to reach sexual maturity within its first year suggests that *Dendrodoa grossularia* can recover from disturbance within 2 years.

Resilience assessment. *Saccharina latissima* and *Dendrodoa grossularia* have rapid recovery rates. Following clearance of *Strongylocentrotus droebachiensis* from 'urchin Barrens' *Saccharina latissima* was a rapid colonizer appearing after a few weeks. Furthermore *Saccharina latissima* can reach maturity within 15-20 months (Birkett et al., 1998). *Dendrodoa grossularia* can reach sexual maturity within 1 year of growth and can rapidly recover following severe habitat alteration. Resilience has therefore been assessed as '**High**'.

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 lattisma* growth (Müller *et al*., 2009). Gametophytes can develop in ≤23°C (Lüning, 1990). Optimal temperature for *Saccharina latissima* sporophyte growth was 10-15°C (Bolton & Lüning, 1982), while reported growth was inhibited by 50-70% at 20°C and all experimental specimens completely disintegrated after 7 days at 23°C. In the field, *Saccharina latissima* has however shown significant regional variation in its acclimation response to changing environmental conditions. For example Gerard & Dubois (1988) found *Saccharina latissima* sporophytes which were regularly exposed to ≥20°C could tolerate these high 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 *Saccharina latissima* to a change in temperatures is likely to be locally variable.

Andersen et al. (2011) transplanted *Saccharina latissima* in the Skagerrak region, Norway and from 2006-2009. There was annual variation however high mortality occurred from August-November within each year of the experiment. In 2008 of the original 17 sporophytes 6 survived from March-September (approx. 65% mortality rate). All surviving sporophytes were heavily fouled by epiphytic organisms (estimated cover of 80 & 100%). Between 1960 and 2009, sea surface temperatures in the region have regularly exceeded 20°C and so has the duration which temperatures remain above 20°C. High sea temperatures has been linked to slow growth of *Saccharina latissima* which is likely to decrease the photosynthetic ability of, and increase the vulnerability of *Saccharina latissima* to epiphytic loading, bacterial and viral attacks (Anderson *et al*., 2011). These factors combined with establishment of annual filamentous algae in Skagerrak, Norway are likely to prevent the establishment of self sustaining populations in the area (Anderson *et al*., 2011; Moy & Christie, 2012).

Dendrodoa grossularia gamete release occurs from spring-autumn, with peaks in early spring and another in late summer. Gamete release is reduced at temperatures above 15°C and totally suppressed above ca 20°C (Miller, 1954). At the time of writing no information could be found on the upper temperature threshold of mature *Dendrodoa grossularia*. However, *Dendrodoa grossularia* is at its southern range edge within the UK and therefore a dramatic increase in temperature that is outside the normal range for the UK may cause mortality.

IR.MIR.KT.SlatT is recorded exclusively within the south west UK (Connor *et al*., 2004), where temperature ranges from 8-16°C (Beszczynska-Möller & Dye, 2013).

Sensitivity assessment. A 2°C increase for one year may impair *Saccharina latissima* sporophyte growth but otherwise not affect the characterizing species. *Saccharina latissima* populations that are not acclimated to >20°C may incur mass mortality within 3 weeks of exposure. Therefore, an increase of 5°C combined with high summer temperatures may cause mass *Saccharina latissima* mortality. Resistance has been assessed as '**None**', and 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 has a lower temperature threshold for sporophyte growth at 0°C (Lüning, 1990). Subtidal red algae can survive at temperatures between -2 °C and 18-23 °C (Lüning, 1990; Kain & Norton, 1990). *Dendrodoa grossularia* is has been recorded from Nottinghambukta, Svalbard where annual temperature can range from 3-5°C.

Sensitivity assessment. An acute or long-term decrease in temperature within the UK, at the benchmark level, is not likely to have a significant effect on IR.MIR.KT.SlatT. Resistance has been assessed as '**High**', resilience as '**High**' and sensitivity as '**Not sensitive**'.

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

Karsten (2007) tested the photosynthetic ability of *Saccharina latissima* under acute 2 and5 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. The affect of long-term salinity changes (>5 days) or salinity >60 PSU on *Saccharina latissima'* photosynthetic ability was not tested. The hypersaline tolerance of *Dendrodoa grossularia* is unknown.

Sensitivity assessment. The evidence suggests that *Saccharina latissima* can tolerate short-term (<5 days) exposure to hypersaline conditions of ≥40‰. Resistance has been assessed as '**High**', resilience as '**High**'. The sensitivity of this biotope to an increase in salinity has been assessed as '**Not Sensitive**'.

Salinity decrease (local)	Low Q: High A: High C: High	High Q: High A: Low C: High	Low Q: High A: Low 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.

Dendrodoa grossularia has been recorded as an abundant component of benthic fauna in Nottinghambukta, Svalbard where salinity can range from 6 and 20‰ (Różycki & Gruszczyński, 1991).

Sensitivity assessment. A decrease in one MNCR salinity scale from 'Variable Salinity' (30-40psu) to 'Reduced Salinity' (18-30 psu) may cause a decline in the photosynthetic ability of *Saccharina latissima* and hence growth. *Dendrodoa grossularia* abundance in Nottinghambukta, Svalbard where salinity is extremely low indicates it would be unaffected. Resistance has been assessed as '**Low**' and resilience as '**High**'. Therefore, sensitivity of this biotope to a decrease in salinity has been assessed as '**Low**'.

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

Peteiro & Freire (2013) measured *Saccharina latissima* growth from 2 sites; the first had maximal water velocities of 0.3m/sec and the second 0.1m/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) found *Saccharina latissima* productivity is reduced in moderately strong tidal streams (≤1m/sec) when compared to weak tidal streams (<0.5m/sec).

Despite the results published in Gerard & Mann (1979) *Saccharina latissima* can characterize or be a dominant in the tide swept biotopes IR.MIR.KT.XKTX & IR.MIR.KT.SlatT, which have been recorded from very strong (>3m/sec) to moderately strong tidal streams (≤1m/sec) (Connor *et al.*, 2004), indicating *Saccharina latissima* can tolerate greater tidal streams than 1m/sec.

Sensitivity assessment. IR.MIR.KT.SlatT is recorded predominantly from strong-moderately strong (0.5-3m/sec) tidal streams. Large scale changes tidal velocities (>1m/sec) may increase the predominance of tide swept biotopes (e.g. IR.MIR.KR.LhypT/X, IR.MIR.KT.XKTX or IR.MIR.KT.SlatT) and replace IR.MIR.KT.SlatT. However, the available evidence suggests that a change in flow velocities of between 0.1-0.2m/sec would have no significant effect on IR.MIR.KT.SlatT. Resistance has been assessed as '**High**', resilience as '**High**'. Sensitivity has been assessed as '**Not Sensitive**' at the benchmark level.

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

IR.MIR.KT.SlatT core records occur exclusively from 0-5m (Connor *et al.*, 2004). An increase in emergence will result in an increased risk of desiccation and mortality of *Saccharina latissima* in shallow examples of the biotope. Removal of canopy forming kelps has also been shown to increase desiccation and mortality of the understory macro-algae (Hawkins & Harkin, 1985). Several mobile species such as sea urchins and brittle stars are likely to move away. However, 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. Resilience has been assessed as '**Low**'. Resistance as '**High**'. The sensitivity of this biotope to a change in emergence is considered as '**Low**'.

Wave exposure changes (local)	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

Wave exposure is one of the principal defining features of kelp biotopes, and changes in wave exposure are likely to alter the relative abundance of the kelp species, grazing and understory community, and hence, the biotope (Birkett *et al*., 2004). *Saccharina latissima* is rarely dominant at wave exposed sites, however if present, develops a short thick stipe and a short, narrow and tightly wrinkled blade (Birkett *et al*., 1998). Furthermore, IR.MIR.KT.SlatT is recorded from sheltered to extremely sheltered sites (Connor *et al*., 2004).

Sensitivity assessment. However a change in near shore significant wave height of 3-5% is unlikely to have any significant effect on IR.MIR.KT.SlatT. Resistance has been assessed as '**High**', resilience as '**High**' and sensitivity 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.

Saccharina latissima sporophytes have a low intolerance to heavy metals, but the early life stages are more intolerant. The effects of copper, zinc and mercury on *Saccharina latissima* have been investigated by Thompson & Burrows (1984). They observed that the growth of sporophytes 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. Little is known about the effects of heavy metals on echinoderms. Bryan (1984) reported that early work had shown that echinoderm larvae were intolerant of heavy metals, e.g. the intolerance of larvae of *Paracentrotus lividus* to copper (Cu) had been used to develop a water quality assessment. Kinne (1984) reported developmental disturbances in *Echinus esculentus* exposed to waters containing 25 µg / l of copper (Cu). Sea-urchins, especially the eggs and larvae, are used for toxicity testing and environmental monitoring (reviewed by Dinnel *et al.* 1988). Taken together with the findings of Gomez & Miguez-Rodriguez (1999) above it is likely that echinoderms are intolerant of heavy metal contamination.

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.

Saccharina latissima fronds, being predominantly subtidal, would not come into contact with freshly released oil but only to sinking emulsified oil and oil adsorbed onto particles (Birkett *et al*., 1998). 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 kelp forests.

Dendrodoa grossularia does grow in the intertidal (Miller, 1954) and may therefore become smothered in the event of an oil spill, however at the time of writing there no evidence to support this.

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.

Radionuclide contamination	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

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: 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. In addition, in tide swept conditions, deoxygenation is likely to highly localised and short lived. 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 six 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 macro-algal communities are relative 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 nutrients may not affect kelps directly, indirect effects such as turbidity may significantly affect photosynthesis. Furthermore organic enrichment may denude the associated community. However, the biotope is probably ‘**Not sensitive**’ at the benchmark levels (i.e. compliance with WFD criteria).

Organic enrichment	Medium Q: High A: High C: High	High Q: High A: Medium C: High	Low Q: High A: High C: High

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 20.22 µM, 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 Norwegian 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.

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Sensitivity assessment. Although nutrients may not affect kelps directly, indirect effects such as turbidity may significantly affect photosynthesis. Furthermore organic enrichment may denude the associated community. Resistance has therefore 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 kelp species would not be able to tolerate (Birkett *et al.*, 1998). 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

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

The species characterizing this biotope are epifauna or epiflora occurring on hard substrata and would be sensitive to the removal of the habitat. However, extraction of rock substratum is considered unlikely and this pressure is considered to be '**Not relevant**' to hard substratum habitats.

Abrasion/disturbance of the surface of the substratum or seabed	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) are unlikely to cause harm to the biotope as a whole, due to the impact's small footprint. *Saccharina latissima* is commercially cultivated, however typically sporophytes are matured on ropes (Handå *et al.* 2013) and not directly extracted from the seabed. Thus evidence to assess the resistance of *Saccharina latissima* to in/direct harvesting or abrasion is limited.

Sensitivity assessment. Abrasion by passing trawls or harvesting of macroalgae is likely remove a large proportion of the kelp biomass. For example in kelp harvesting is likely to remove all the large canopy forming plants (Svendsen, 1972; Christie et al., 1998). However, *Saccharina latissima* has been shown to be an early colonizer with the potential to recover rapidly (Kain, 1967; Lienaas & Christie, 1996). Therefore, resistance has been assessed as '**None**', resilience as '**High**', and sensitivity as '**Low**'.

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

The species characterizing this biotope group are epifauna or epiflora occurring on hard substrata which is resistant to subsurface penetration. The assessment for abrasion at the surface only is therefore considered to equally represent sensitivity to this pressure. This pressure is not thought relevant to hard rock biotopes.

Changes in suspended solids (water clarity)	None Q: High A: High C: High	High Q: High A: High C: High	Medium Q: High A: High C: High

Suspended Particle Matter (SPM) concentration has a linear relationship with sub surface light attenuation (Kd) (Devlin *et al.*, 2008). An increase in SPM results in a decrease in sub-surface light attenuation. Light availability and water turbidity are principal factors in determining kelp depth range (Birkett *et al.*, 1998). Light penetration influences the maximum depth at which kelp species 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 (Birkett *et al.* 1998b; Lüning, 1990). *Laminaria* spp. 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). An increase in water turbidity will likely affect the photosynthetic ability of kelp, decrease abundance and density.

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 '**High**' at the benchmark. Hence, this biotope is regarded as having a sensitivity of '**Medium** 'to this pressure.

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

Smothering by sediment e.g. 5 cm material during a discrete event, is unlikely to damage *Saccharina latissima* sporophytes but may affect holdfast fauna, gametophyte survival, interfere with zoospore settlement and therefore recruitment processes (Moy & Christie, 2012). Given the short life expectancy of *Saccharina latissima* (2-4 years; Parke, 1948)), IR.MIR.KT.SlatT is likely to be dependent on annual *Saccharina latissima* recruitment (Moy & Christie, 2012). Given the microscopic size of the gametophyte, 5 cm of sediment could be expected to significantly inhibit growth. However, laboratory studies showed that kelp gametophytes can survive in darkness for between 6-16 months at 8°C and would probably survive smothering by a discrete event. Once returned to normal conditions the gametophytes resumed growth or maturation within 1 month (Dieck, 1993). Intolerance to this factor is likely to be higher during the peak periods of sporulation and/or spore settlement.

Dendrodoa grossularia is a small ascidian, capable of reaching a size of approx 8.5 mm (Miller, 1954) and is therefore likely to be inundated by deposition of 5 cm of sediment. If inundation is long lasting then the understory community may be adversely affected. However, IR.MIR.KT.SlatT is found within strong-moderately strong (0.5-3 m/sec) and therefore deposited sediments are unlikely to remain for more than a few tidal cycles.

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

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

Smothering by sediment e.g. 30 cm material during a discrete event, is unlikely to damage *Saccharina latissima* sporophytes but may affect holdfast fauna, gametophyte survival, interfere with zoospore settlement and therefore recruitment processes (Moy & Christie, 2012). Given the short life expectancy of *Saccharina latissima* (2-4 years Parke, 1948)), IR.MIR.KT.SlatT is likely to be dependent on annual recruitment (Moy & Christie, 2012). Given the microscopic size of the gametophyte, 30cm of sediment could be expected to significantly inhibit growth. However, laboratory studies showed that gametophytes can survive in darkness for between 6-16 months at 8°C and would probably survive smothering by a discrete event. Once returned to normal conditions the gametophytes resumed growth or maturation within 1 month (Dieck, 1993).

Intolerance to this factor is likely to be higher during the peak periods of sporulation and/or spore settlement.

Dendrodoa grossularia is a small ascidian, capable of reaching a size of approx 8.5mm (Miller, 1954) and is therefore likely to be inundated by deposition of 30 cm of sediment. If inundation is long lasting then the understory community may be adversely affected. However, IR.MIR.KT.SlatT is found within strong-moderately strong (0.5-3m/sec) and therefore deposited sediments are likely to be cleared rapidly, but inundation is likely to cause mortality in the understory community.

Sensitivity assessment. Resistance has been assessed as ‘**Low**’, 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. There is no evidence to suggest that litter would affect kelp.

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

Saccharina lattissima has no hearing perception but vibrations may cause an impact, however no studies exist to support an assessment (where relevant).

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

There is no evidence to suggest that anthropogenic light sources would affect IR.MIR.KT.SlatT. Shading (e.g. by construction of a pontoon, pier etc) could adversely affect IR.MIR.KT.SlatT 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. IR.MIR.KT.SlatT is already affected by high water turbidity (Connor *et al*., 2004), and *Saccharina lattissima* is therefore relatively sparse.

Sensitivity assessment. Resistance is probably '**Low**', with a '**High**' resilience and a sensitivity of '**Low**', 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 to seabed habitats. NB. Collision by grounding vessels is addressed under 'surface abrasion'.

Visual disturbance	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence

Introduction or spread of invasive non-indigenous species	None Q: Medium A: High C: High	Very Low Q: Medium A: High C: High	High Q: Medium 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*, 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).

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 is unlikely.

Sensitivity assessment. Resistance to the pressure is considered '**None**', and resilience '**Very Low**'. The sensitivity of this biotope to INIS is assessed as '**High'**.

Introduction of microbial pathogens	Medium Q: Medium A: High C: Medium	High Q: Low A: NR C: NR	Low Q: Low A: Low C: Low

Saccharina latissima 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 (Peters & Scaffelke, 1996). Infection can reduce growth rates of host algae.

Sensitivity assessment. Resistance to the pressure is considered '**Medium**', and resilience '**High**'. The sensitivity of this biotope to 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

Saccharina latissima is commercially cultivated, however typically sporophytes are matured on ropes (Handå et al 2013) and not directly extracted from the seabed, as is the case with *Laminaria hyperborea* (see Christie *et al*., 1998). As a consequence related literature on which to assess the "resistance" of *Saccharina latissima* to targeted harvesting is sparse. Similarly, at the time of writing, no evidence could be found to suggest that *Dendrodoa grossularia* is commercially exploited.

Sensitivity assessment. At the time of writing none of the characterising species are commercially extracted from the seabed. If extracted in the future resistance would need to be re-assessed. This pressure has been assessed as '**Not Relevant'.**

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

Incidental removal of characterizing species from this biotope would likely have a fundamental effect on the ecology. *Laminaria digitata* is commercially extracted *Saccharina latissima* is commercially cultivated, however typically sporophytes are matured on ropes (Handå et al 2013) and not directly extracted from the seabed, as is the case with *Laminaria hyperborea* (see Christie *et al*., 1998). Similarly *Dendrodoa grossularia* is not currently a commercially exploited species. As a consequence relevant literature on which to assess the "resistance" of IR.MIR.KT.SlatT to incidental harvesting is sparse. If removed the characterizing species are likely to recover within 2 years.

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

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