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Mixed kelp with foliose red seaweeds, sponges and ascidians on sheltered tide-swept infralittoral rock

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

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2015-10-20

A report from:
The Marine Life Information Network, Marine Biological Association of the United Kingdom.

Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [https://www.marlin.ac.uk/habitats/detail/1043]. All terms and the MarESA methodology are outlined on the website (https://www.marlin.ac.uk)

This review can be cited as:
Stamp, T.E., 2015. Mixed kelp with foliose red seaweeds, sponges and ascidians on sheltered tide-swept infralittoral rock. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. DOI https://dx.doi.org/10.17031/marlinhab.1043.1

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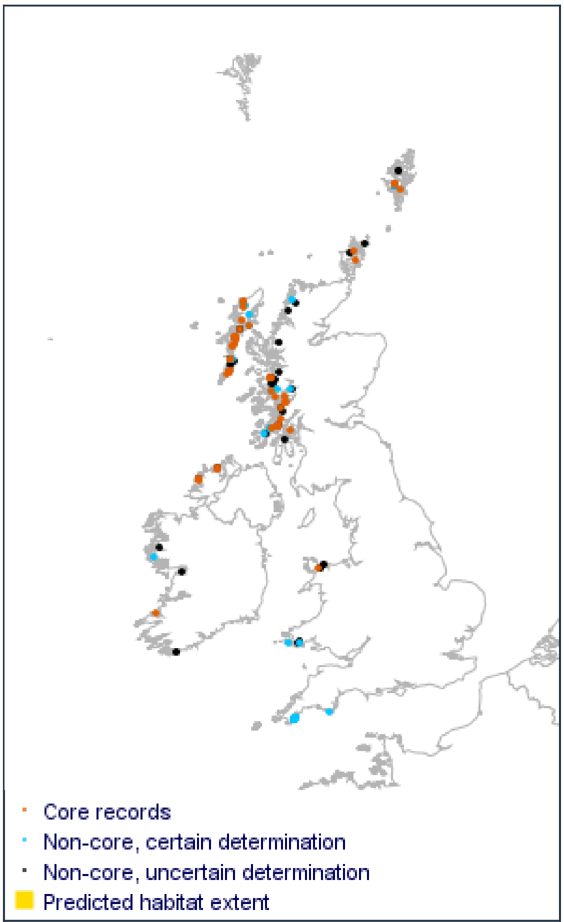

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Thomas Stamp **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A3.222	Mixed kelp with foliose red seaweeds, sponges and ascidians on sheltered tide-swept infralittoral rock
JNCC 2015	IR.MIR.KT.XKT	Mixed kelp with foliose red seaweeds, sponges and ascidians on sheltered tide-swept infralittoral rock
JNCC 2004	IR.MIR.KT.XKT	Mixed kelp with foliose red seaweeds, sponges and ascidians on sheltered tide-swept infralittoral rock
1997 Biotope		

Description

Bedrock and boulders, often in tide-swept areas, that are subject to scouring or periodic burial by sand, characterized by a canopy of mixed kelps such as *Saccharina latissima*, *Laminaria hyperborea* and *Saccorhiza polyschides* and the brown seaweed *Desmarestia aculeata*; there may also be an understorey of foliose seaweeds that can withstand scour such as *Plocamium cartilagineum*, *Chondrus crispus*, *Dilsea carnosa*, *Callophyllis laciniata* as well as the filamentous *Heterosiphonia plumosa* and the foliose brown seaweed *Dictyota dichotoma*. The perennial red seaweed *Brongniartella byssoides* re-grows in the summer months. The *L. hyperborea* stipes often support a growth of epiphytes, such as *Delesseria sanguinea*, *Phycodrys rubens* and *Cryptopleura ramosa*. The scour can reduce the rock surface to bare coralline crusts at times; sponge crusts and the colonial ascidian *Botryllus schlosseri* can also grow on the stipes and holdfasts. The faunal diversity on the rock is usually low and restricted to robust, low-profile animals such as the tube-building polychaete *Spirobranchus triqueter*, the barnacle *Balanus crenatus*, encrusting bryozoans such as *Membranipora membranacea*, the anthozoan *Urticina felina*, the starfish *Asterias rubens* and the urchin *Echinus esculentus*. Deeper sites support more hydroids and bryozoans, particularly *Bugula* spp. Where this biotope occurs in very shallow water *Laminaria digitata* may be found in combination with the other kelp species. Other species present only in shallow water include the red algae *Corallina officinalis* and the sand-binding alga *Rhodothamniella floridula*.

Depth range

-

Additional information

-

Listed By

- none -

Further information sources

Search on:

G G JNCC

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

IR.MIR.KT.XKT & IR.MIR.KT.XKTX are defined by bedrock reefs and mixed substrata of boulders, cobbles, pebbles and gravel, typically found in strong tidal streams. The community is characterized by mixed kelp canopies of *Laminaria hyperborea* and *Saccharina latissima* (syn. *Laminaria saccharina*). Dense stands of the brown seaweed *Halidrys siliquosa* can occur within the kelp along with *Dictyota dichotoma*. Kelp stipes may also support prolific growths of foliose red seaweeds such as *Phycodrys rubens*, *Membranoptera alata*, *Delesseria sanguinea* and *Plocamium cartilagineum*. The dominance of kelp species can vary between sites however as substrata stability decreases, as in IR.MIR.KT.XKTX, *Saccharina latissima* becomes the more dominant canopy forming species (Connor *et al.*, 2004).

In undertaking this assessment of sensitivity, account is taken of knowledge of the biology of all characterizing species in the biotope. There is an abundance of literature for regeneration of mono-specific *Laminaria hyperborea* beds, however at the time of writing there is limited research for the recovery of mixed kelp canopies. For this sensitivity assessment *Laminaria hyperborea* and *Saccharina latissima* are the primary foci of research, however have been researched independently and inter-specific competition may influence recover times. It is also recognized that the understory red seaweed communities also define the biotope. Examples of important species groups are mentioned where appropriate.

Resilience and recovery rates of habitat

In favourable conditions *Laminaria hyperborea* can recover following disturbance events reaching comparable plant densities and size to pristine *Laminaria hyperborea* beds within 2-6 years (Kain, 1979; Birkett *et al.*, 1998; Christie *et al.*, 1998). Holdfast communities may recover in 6 years (Birkett *et al.*, 1998). Full epiphytic community and stipe habitat complexity regeneration requires over 6 years to recover (possibly 10 years). These recovery rates were based on discrete kelp harvesting events and recurrent disturbance occurring frequently within 2-6 years of the initial disturbance is likely to lengthen recovery time (Birkett *et al.*, 1998, Burrows *et al.*, 2014). 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 however within 2 years of clearance the blocks were dominated by *Laminaria hyperborea*.

Laminaria hyperborea has a heteromorphic life strategy, A vast number of zoospores (mobile asexual spores) are released into the water column between October-April (Kain & Jones, 1964). Zoospores settle onto rock substrata and develop into dioecious gametophytes (Kain, 1979) which, following fertilization, develop into sporophytes and mature within 1-6 years (Kain, 1979; Fredriksen *et al.*, 1995; Christie *et al.*, 1998). *Laminaria hyperborea* zoospores have a recorded dispersal range of approximately .200m (Fredriksen *et al.*, 1995). However, zoospore dispersal is greatly influenced by water movements, and 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).

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 re-dominate 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.

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 2.25 m 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 34,000km 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.

Resilience assessment. Of the 2 kelp species (*Laminaria hyperborea* and *Saccharina latissima*) that characterize IR.MIR.KT.XKT & IR.MIR.KT.XKTX, *Laminaria hyperborea* is the slowest to recover following disturbance. *Laminaria hyperborea* can regenerate from disturbance within a period of 1-6 years, and the associated community within 7-10 years. *Saccharina latissima* has reportedly a rapid recovery rate or re-generation time, following clearance of *Strongylocentrotus droebachiensis* from 'urchin Barrens' *Saccharina latissima* was a rapid colonizer appearing after a few weeks, and can reach maturity within 15-20 months (Birkett et al., 1998). Due to comparatively slow growth rates resilience estimates are based on *Laminaria hyperborea*, however the recovery of *Saccharina latissima* and the understory red seaweed is accounted for where relevant. Resilience has therefore been assessed as '**Medium**'.

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	Low Q: High A: High C: High	High Q: High A: High C: High	Low Q: High A: High C: High

Kain (1964) stated that *Laminaria hyperborea* sporophyte growth and reproduction could occur within a temperature range of 0-20°C. Upper and lower lethal temperatures have been estimated at between 1-2°C above or below the extremes of this range (Birkett *et al.*, 1988). Above 17°C *Laminaria hyperborea* gamete survival is reduced (Kain, 1964 & 1971) and gametogenesis is inhibited at 21°C (Dieck, 1992). It is therefore likely that *Laminaria hyperborea* recruitment will be impaired at a sustained temperature increase of above 17°C. Sporophytes however can tolerate slightly higher temperatures of 20°C. Temperature tolerances for *Laminaria hyperborea* are also seasonally variable and temperature changes are less tolerated in winter months than summer months (Birkett et al., 1998).

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 1960-2009, 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).

IR.MIR.KT.XKT & IR.MIR.KT.XKTX 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 (Beszczynska-Möller & Dye, 2013).

Sensitivity assessment. A 2°C increase for one year may impair *Laminaria hyperborea* recruitment processes and *Saccharina latissima* sporophyte growth but otherwise not affect the characterizing species. A 5°C increase for one month combined with high UK summer temperatures is likely to affect *Laminaria hyperborea* sporophyte growth. *Saccharina latissima* populations that are not acclimated to >20°C may incur mass mortality within 3 weeks of exposure. Resistance has been assessed as '**Low**', to reflect the potential mass mortality effect of sudden temperature increases on *Saccharina latissima*, and resilience as '**High**'. Sensitivity has been assessed as '**Low**'.

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

Kain (1964) stated that *Laminaria hyperborea* sporophyte growth and reproduction could occur within a temperature range of 0-20°C. Upper and lower lethal temperatures have been estimated at between 1-2°C above or below the extremes of these ranges (Birkett *et al.*, 1988). *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).

Sensitivity assessment. Both *Laminaria hyperborea* and *Saccharina latissima* have northern distributions (Birkett *et al.*, 1998). An acute or long-term decrease in temperature within the UK, at the benchmark level, is not likely to have any dramatic effect on biotope structure. Resistance has been assessed as '**High**', resilience as '**High**' and sensitivity as '**Not sensitive**'.

Salinity increase (local)	Low Q: High A: High C: High	Medium Q: High A: Low C: High	Medium Q: High A: Low C: NR

Lüning (1990) suggest that 'kelps' are stenohaline, their general tolerance to salinity as a phenotypic group covering 16-50 psu over a 24 hr period. Optimal growth probably occurs between 30-35 psu and growth rates are likely to be affected by periodic salinity stress. Birkett *et al.* (1998) suggested that long-term increases in salinity may affect *Laminaria hyperborea* growth and may result in loss of affected kelp, and therefore loss of the biotope.

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.

Sensitivity assessment. The evidence suggests that *Saccharina latissima* can tolerate exposure to hypersaline conditions of ≥40‰. However, optimal salinities for *Laminaria hyperborea* growth are assumed to be 30-35 psu. Hence, increases in salinity to >40‰ may cause mortality for *Laminaria hyperborea*. Resistance has been assessed as '**Low**', resilience as '**Medium**'. The sensitivity of this biotope to an increase in salinity has been assessed as '**Medium**'.

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

Lüning (1990) suggest that 'kelps' are stenohaline, their general tolerance to salinity as a phenotypic group covering 16 - 50 psu over a 24 hr period. Optimal growth probably occurs between 30-35 psu and growth rates are likely to be affected by periodic salinity stress. Birkett *et al.* (1998) suggest that long-term changes in salinity may result in loss of affected kelp. Hopkin & Kain (1978) tested *Laminaria hyperborea* sporophyte growth at various low salinity treatments. The results showed that *Laminaria hyperborea* sporophytes could grow 'normally' at 19 psu, growth was reduced at 16 psu and did not grow at 7 psu.

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. 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.

Sensitivity assessment. IR.MIR.KT.XKT & IR.MIR.KT.XKTX are recorded in both full and variable salinity (18-40) A decrease in one MNCR salinity scale to 'Reduced Salinity' (18-30 psu) may result in a decrease of *Laminaria hyperborea* sporophyte growth and *Saccharina latissima*. Resistance has been assessed as '**Low**' and resilience as '**Medium**'. Therefore, sensitivity of this biotope to a decrease in salinity has been assessed as '**Medium**'.

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 0.3 m/sec and the second 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) found *Saccharina latissima* productivity is reduced in moderately strong tidal streams (≤1m/sec) when compared to weak tidal streams (<0.5 m/sec). Despite these results where the substratum is unstable *Saccharina lattissima* can become the dominant canopy forming kelp within tide swept conditions, as in IR.MIR.KT.XKTX (Connor *et al*., 2004).

Kregting *et al.* (2013) measured *Laminaria hyperborea* blade growth and stipe elongation from an exposed and a sheltered site in Strangford Lough, Ireland, from March 2009-April 2010. Maximal significant wave height (Hm0) was 3.67 & 2m at the exposed and sheltered sites, and maximal water velocity (Velrms) was 0.6 & 0.3 m/s at the exposed and sheltered sites respectively. Despite the differences in wave exposure and water velocity there was no significant difference in *Laminaria hyperborea* growth between the exposed and sheltered sites. Therefore water flow was found to have no significant effect on *Laminaria hyperborea* growth at the observed range of water velocities.

Sensitivity assessment. IR.MIR.KT.XKT & IR.MIR.KT.XKTX are predominantly recorded from “Moderately strong” tidal streams (0.5-1.5 m/sec). Due to the range of tidal velocities that these biotopes are recorded within a change in flow of between 0.1-0.2m/sec would likely have no significant effect on *Laminaria hyperborea* or *Saccharina latissima* growth or productivity. 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	Medium Q: High A: Low C: High	Medium Q: Low A: Low C: Low

IR.MIR.KT.XKT & IR.MIR.KT.XKTX are shallow water biotopes, recorded predominantly from 0-5 m BCD. An increase in emergence will result in an increased risk of desiccation and mortality of the dominant kelp species (*Laminaria hyperborea* & *Saccharina latissima*). 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, brittle stars and feather 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 ‘**Medium**’. The sensitivity of this biotope to a change in emergence is considered as ‘**Medium**’.

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

Kregting *et al.*(2013) measured *Laminaria hyperborea* blade growth and stipe elongation from an exposed and a sheltered site in Strangford Lough, Ireland from March 2009-April 2010. Wave exposure was found to be between 1.1. to 1.6 times greater between the exposed and sheltered sites. Maximal significant wave height (Hm0) was 3.67 & 2m at the exposed and sheltered sites. Maximal water velocity (Velrms) was 0.6 & 0.3m/s at the exposed and sheltered sites. Despite the differences in wave exposure and water velocity there was no significant difference in *Laminaria hyperborea* growth between the exposed and sheltered site.

However, Pederson *et al.* (2012) observed *Laminaria hyperborea* biomass, productivity and density increased with greater wave exposure. At low wave exposure *Laminaria hyperborea* canopy forming plants were smaller, had lower densities and had higher mortality rates. At low wave exposure, high epiphytic loading on *Laminaria hyperborea* was suggested to impair photosynthesis, nutrient uptake, and increase the drag of the host *Laminaria hyperborea* during extreme storm events. The morphology of kelp stipe and blades vary in different water flows and wave exposures water flow. In wave exposed areas, for example, *Laminaria hyperborea* develops a long and flexible stipe and this is probably a functional adaptation to strong water movement (Sjøtun *et al.*, 1998). In addition, the lamina becomes narrower and thinner in strong currents (Sjøtun & Fredriksen, 1995).

Saccharina latissima is rarely found at wave exposed sites (Birkett *et al.*, 1998). *Saccharina latissima*, if present, develops a short thick stipe and a short, narrow and tightly wrinkled blade (Birkett *et al.*, 1998).

Sensitivity assessment. 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, understory community and hence the biotope. IR.MIR.KT.XKT & IR.MIR.KT.XKTX are recorded from wave sheltered sites, so that an increase in wave exposure (e.g. to moderate or higher) is likely to result in modification of the community and loss of the biotope. However a change in near shore significant wave height of 3-5% is unlikely to have any significant effect on IR.MIR.KT.XKT & IR.MIR.KT.XKTX. 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.

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 a,.* (1999) reported that Hg was very toxic to macrophytes. Similarly, Hopkin & Kain (1978) demonstrated sub-lethal effects of heavy metals on *Laminaria hyperborea* 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). *Echinus esculentus* recruitment is likely to be impaired by heavy metal contamination due to the intolerance of its larvae. *Echinus esculentus* are long-lived and poor recruitment may not reduce grazing pressure in the short term. 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.

Sporophytes of *Saccharina latissima* 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.

Laminaria hyperborea and *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. Similarly, surveys of subtidal communities at a number sites between 1-22.5m below chart datum, including *Laminaria hyperbora* communities, showed no noticeable impacts of the Sea Empress oil spill and clean up (Rostron & Bunker, 1997). An assessment of holdfast fauna in *Laminaria* showed that although species richness and diversity decreased with increasing proximity to the Sea Empress oil spill, overall the holdfasts contained a reasonably rich and diverse fauna, even though oil was present in most samples (Sommerfield & Warwick, 1999). Laboratory studies of the effects of oil and dispersants on several red algae species, including *Delesseria sanguinea* (Grandy 1984; cited in Holt *et al.*, 1995) concluded that they were all sensitive to oil/ dispersant mixtures, with little differences between adults, sporelings, diploid or haploid life stages. Holt *et al.* (1995) concluded that *Delesseria sanguinea* is probably generally sensitive of chemical contamination.

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.

Although *Laminaria hyperborea* sporelings and gametophytes are intolerant of atrazine (and probably other herbicides) overall they may be relatively tolerant of synthetic chemicals (Holt *et al.*, 1995; Johansson, 2009). *Laminaria hyperborea* survived within >55m from the acidified halogenated effluent discharge polluting Amlwch Bay, Anglesey, albeit at low density. These specimens were greater than 5 years of age, suggesting that spores and/or early stages were more intolerant (Hoare & Hiscock, 1974). *Patella pellucida* was excluded from Amlwch Bay by the pollution and the species richness of the holdfast fauna decreased with proximity to the effluent discharge; amphipods were particularly intolerant although polychaetes were the least affected (Hoare & Hiscock, 1974). The richness of epifauna/flora decreased near the source of the effluent and epiphytes were absent from *Laminaria hyperborea* stipes within Amlwch Bay. The red alga *Phyllophora membranifolia* was also tolerant of the effluent in Amlwch Bay.

Smith (1968) also noted that epiphytic and benthic red algae were intolerant of dispersant or oil contamination due to 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. *Delesseria sanguinea* was probably to most intolerant since it was damaged at depths of 6m (Smith, 1968). Holt *et al.*, (1995) suggested that *Delesseria sanguinea* is probably generally sensitive of chemical contamination. Although *Laminaria hyperborea* may be relatively insensitive to synthetic chemical pollution, evidence suggests that grazing gastropods, amphipods and red algae are sensitive. Loss of red algae is likely to reduce the species richness and diversity of the biotope and the understorey may become dominated by encrusting corallines; however, red algae are likely to recover relatively quickly.

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: High 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. In addition, IR.MIR.KT.XKT & IR.MIR.KT.XKTX are tide swept so that any deoxygenation would be highly localised and transient.

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 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).

Holt *et al.* (1995) suggest that *Laminaria hyperborea* may be tolerant of organic enrichment since healthy populations are found at ends of sub littoral untreated sewage outfalls in the Isle of Man. Increased nutrient levels e.g. from sewage outfalls, has been associated with increases in abundance, primary biomass and *Laminaria hyperborea* stipe production but with concomitant decreases in species numbers and diversity (Fletcher, 1996). Increases in ephemeral and opportunistic algae are associated with reduced numbers of perennial macrophytes (Fletcher, 1996). Increased nutrients may also result in phytoplankton blooms that increase turbidity.

Sensitivity assessment. Although nutrients may not affect kelps directly, indirect effects such as turbidity may significantly affect photosynthesis. Furthermore nutrient enrichment may denude the associated community. However, the biotope is probably '**Not sensitive**' (resistance is 'High' and resilience is 'High) at the benchmark level (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 20.22µM, 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 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 dependent.

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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

Not relevant to 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

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

Not relevant, please refer to pressure "Abrasion/disturbance of the substratum on the surface of the seabed".

Changes in suspended solids (water clarity)	Low Q: High A: High C: High	Medium 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 down to depths at which the light levels are reduced to one 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 *Laminaria hyperborea* 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 *Laminaria hyperborea* and *Laminaria ochroleuca* and decrease *Laminaria hyperborea* abundance and density (see sub-biotope-IR.MIR.KR.Lhyp.Pk). Kain (1964) suggested that early *Laminaria hyperborea* gametophyte development could occur in the absence of light. Furthermore, observations from south Norway found that a pool of *Laminaria hyperborea* recruits could persist growing beneath *Laminaria hyperborea* canopies for several years, indicating that sporophyte growth can occur in light-limited environments (Christe *et al.*, 1998). However in habitats exposed to high levels of suspended silts *Laminaria hyperborea* is out-competed by *Saccharina latissima*, a silt tolerant species, and thus, a decrease in water clarity is likely to decrease the abundance of *Laminaria hyperborea* in the affected area (Norton, 1978).

Sensitivity Assessment. Changes in water clarity are likely to affect photosynthetic rates and enable Saccharina latissima to compete more successfully with Laminaria hyperborea. A decrease in turbidity is likely to support enhanced growth (and possible habitat expansion) and is therefore not considered in this assessment. An increase in water clarity from clear to intermediate (10-100 mg/l) represents 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 significant decline and resistance to this pressure is assessed as '**Low**'. Resilience to this pressure is probably '**Medium**' at the benchmark. Hence, this biotope is assessed 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)	Low 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. 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, 30 cm 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**', and 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 macro-algal growth. Shading of the biotope (e.g. by 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 laminarian abundance from forest to park type biotopes.

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. Collision from grounding vessels is addressed under abrasion above.

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	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 1.65 m (Birkett *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) and *Laminaria hyperborea* (Hieser *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 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 70deg C (Wotton *et al.*, 2004) however numerous other eradication attempts have failed, and as noted by Fletcher & Farrell, (1999) once established *Undaria pinnatifida* resists most attempts of long-term removal. The biotope is unlikely to fully recover until *Undaria pinnatifida* is fully removed from the habitat, which as stated above is unlikely to occur.

Sensitivity assessment. Resistance to the pressure is considered '**Low**', and resilience '**Very low**', the non-native species would need to be removed before recovery can occur. The sensitivity of this biotope to introduction of microbial pathogens 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

Laminaria hyperborea and *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	Low Q: High A: High C: High	High Q: High A: High C: High	Low Q: High A: High C: High

There has been recent commercial interest in *Saccharina lattisma* as a consumable called 'sea vegetables' (Birkett *et al.*, 1998). *Laminaria hyperborea* is also extracted on a commercial scale in southern Norway, primarily for alagnate (Werner & Kraan, 2004).

Commercial *Laminaria hyperborea* trawling occurs in Norway, during which Christie *et al.* (1998) reports all large canopy forming sporophytes are removed, sub-canopy sporophytes and understory community however remain intact. *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 direct harvesting is limited.

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

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

Incidental/accidental removal of *Laminaria hyperborea* and *Saccharina latissima* is likely to cause similar effects to that of direct harvesting; as such the same evidence has been used for both pressure assessments. There has been recent commercial interest in *Saccharina latissima* as a consumable called 'sea vegetable'' (Birkett *et al.*, 1998). *Laminaria hyperborea* is also extracted on a commercial scale in southern Norway, primarily for alginates (Werner & Kraan, 2004).

Commercial *Laminaria hyperborea* trawling occurs in Norway, during which Christie *et al.* (1998) reports all large canopy forming sporophytes are removed, sub-canopy sporophytes and understory community however remain intact. *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 direct harvesting is limited.

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

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