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# Silted cape-form *Laminaria hyperborea* on very sheltered infralittoral rock

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

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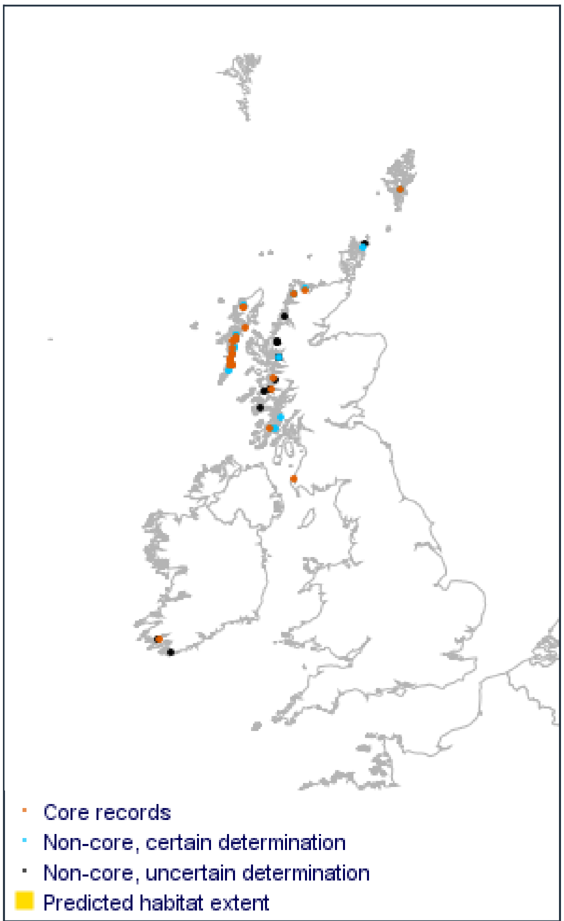


17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

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

# Summary

## UK and Ireland classification

| | | |
|---|---|---|
| **EUNIS 2008** | A3.314 | Silted cape-form *Laminaria hyperborea* on very sheltered infralittoral rock |
| **JNCC 2015** | IR.LIR.K.LhypCape | Silted cape-form *Laminaria hyperborea* on very sheltered infralittoral rock |
| **JNCC 2004** | IR.LIR.K.LhypCape | Silted cape-form *Laminaria hyperborea* on very sheltered infralittoral rock |
| **1997 Biotope** | | |

## Description

Cape-form of the kelp *Laminaria hyperborea* on very silted rock, particularly in extremely sheltered sealochs of western Scotland. Below the huge kelp fronds (which often trail onto the seabed) foliose seaweeds form a silted understorey on the rock including *Phycodrys rubens*, *Delesseria* *sanguinea*, *Cryptopleura ramosa* and *Plocamium cartilagineum* as well as coralline crusts. At some sites the filamentous red seaweed *Bonnemaisonia hamifera*, *Heterosiphonia plumosa* and *Brongniartella byssoides* may carpet the seabed. Ascidians, particularly *Ascidiella aspersa*, *Ascidia mentula*, *Ciona intestinalis* and *Clavelina lepadiformis* thrive well in these conditions. The echinoderms *Antedon bifida*, *Echinus esculentus* and *Asterias rubens* are often present along with the gastropod *Gibbula cineraria*. An abundant growth of the hydroid *Obelia geniculata* can cover the silted kelp fronds along with the bryozoan *Membranipora membranacea*. The anthozoan *Caryophyllia smithii* can be present among the kelp holdfasts. The tube-building polychaete *Spirobranchus triqueter* can be present on the rock surface along with the crab *Necora puber*. This biotope generally occurs on shallow bedrock or boulder slopes or isolated rocks protruding through muddy sediment. (Information from Connor *et al*., 2004; JNCC, 2105).

## Depth range

0-5 m, 5-10 m

## Additional information

-

## Listed By

- none -

## Further information sources

Search on:

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# Sensitivity review

## Sensitivity characteristics of the habitat and relevant characteristic species

IR.LIR.K.LhypCape is defined by abundant growth of the cape-form of *Laminaria hyperborea*. Below the kelp fronds, red seaweeds such as *Phycodrys rubens*, *Delesseria sanguinea*, *Cryptopleura ramosa* and *Plocamium cartilagineum* form a silted understory. An abundant growth of the hydroid *Obelia geniculata* and bryozoan *Membranipora membranacea* can cover the silted kelp fronds. This biotope is often present on rocky outcrops surrounded by muddy sediments in extremely sheltered to sheltered wave exposure, such as Scottish sea lochs or Irish sea loughs. Solitary ascidians such as *Ascidiella aspersa*, *Ascidia mentula*, *Ciona intestinalis* and *Clavelina lepadiformis* can also thrive in this habitat, however these species can also be found on deeper, nearby rock, beyond the limit of foliose seaweeds, and are therefore not thought of as defining species in IR.LIR.K.LhypCape.

The cape-form of *Laminaria hyperborea* (*Laminaria hyperborea f. cucullata*) is a growth form of *Laminaria hyperborea*, described by Svendsen & Kain (1971) The cape-form *Laminaria hyperborea* has a poorly developed and weak holdfast. The stipe is bent/twisted and short, normally less than 50 cm long. The frond is thin (Sjøtun *et al*., 1998), brittle and easily torn, heart shaped at the base, undivided and broad, forming a draping "cape" or "apron" over the rock (Svendsen & Kain 1971). IR.LIR.K.LhypCape is recorded from ca 0-20 m below chart datum, typically on heavily silted rocky outcrops within sheltered-extremely sheltered habitats, e.g. Scottish sea lochs or Irish sea loughs (Svendsen & Kain, 1971; Connor *et al*., 2004). While the geographic distribution of cape-form *Laminaria hyperborea* is documented within the UK (Connor *et al*., 2004) only one reference (Svendsen & Kain 1971) comprehensively describes it's morphology and vertical/depth distribution. Despite the relative scarcity of information covering cape-form *Laminaria hyperborea*, much is known on the life history (Kain & Jones, 1964; Christie *et al*., 1998) and recovery (Kain, 1975; Christie *et al*., 1998) of *Laminaria hyperborea* in wave exposed biotopes (e.g. IR.HIR.KFaR.LhypR). Inferences can therefore be made on the likely effect of the pressures assessed within this review on cape-form *Laminaria hyperborea* and hence the habitat structure of IR.LIR.K.LhypCape. Where possible references to cape-form *Laminaria hyperborea'* distinctive features have been made throughout this review.

In undertaking this assessment of sensitivity, account is taken of knowledge of the biology of all characterizing species/taxa in the biotope. However, 'indicative species' are particularly important in undertaking the assessment. For this sensitivity assessment the cape-form of *Laminaria hyperborea* is the key characteristic and structural species, and hence the primary focus of research, however it is recognized that the understory red seaweed community also define the biotope. Examples of important species groups are mentioned where appropriate.

Information on the cape-form *Laminaria hyperborea* is limited. However, where information was lacking inferences were made from typical growth form *Laminaria hyperborea* references from exposed biotopes e.g. IR.HIR.Kfar.LhypR. Please note that *Laminaria digitata* can also form a 'cape' form (*Laminaria digitata* f. *cucullata*). Therefore, it is possible that records of the 'cape-form' in this biotope may describe either species. However, in the absence of a definitive survey records, the following review assumes that only *Laminaria hyperborea* is present.

## Resilience and recovery rates of habitat

Cape-form *Laminaria hyperborea* (*Laminaria hyperborea f. cucullata*) is found from ca 4-25 m Below Chart Datum (BCD) (Svendsen & Kain, 1971; Connor *et al*., 2004). Svendsen & Kain (1971) conducted a transplantation experiment to observe if cape-form fronds (of cape-form *Laminaria hyperborea*) were a phenotypic response of *Laminaria hyperborea* to low water movement. At a sheltered location in southern Norway, six cape-form *Laminaria hyperborea* were transplanted from 15 m BCD to 0.5 m BCD and ten *Laminaria hyperborea* vice versa. After six months none of the cape-form *Laminaria hyperborea* had survived at 0.5 m and only their holdfasts were still present. Of the ten *Laminaria hyperborea* transplanted to 15 m BCD, four survived and produced cape-form fronds. Svendsen & Kain (1971) noted whilst transporting the six cape-form *Laminaria hyperborea*, the cape-form fronds were very fragile and often ruptured under their own weight. Svendsen & Kain (1971) suggested increased wave action at 0.5 m was the reason why none of the cape-form *Laminaria hyperborea* survived beyond six months. Although the wave exposure at the site was not formally tested, this evidence suggests that cape-form *Laminaria hyperborea* is highly sensitive to physical disturbance e.g. from water movement (wave action and/or tidal movement).

A number of review and experimental publications have assessed the recovery of *Laminaria hyperborea* beds and the associated community within high energy habitats (e.g. IR.HIR.KFaR.LhypR). If environmental conditions are favourable *Laminaria hyperborea* can recover following disturbance 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 (possibly 10 years) (Christie *et al.*, 1998). These recovery rates were based on observations of discrete kelp harvesting events, 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). Siltation within IR.LIR.K.LhypCape may provide a physical barrier to *Laminaria hyperborea* zoospore settlement, recurrent siltation may also decrease light and therefore decrease gametophyte survival. Dieck (1993) demonstrated that *Laminaria hyperborea* gametophytes can survive in darkness for between 6 -16 months at 8°C, however Kain (1964) demonstrated that gametophyte survival rate and sporophyte development dramatically decreases beyond 10 days of darkness. Heavy deposition of sediment/siltation could therefore significantly inhibit recruitment pathways and therefore recovery of IR.LIR.K.LhypCape following disturbance. *Laminaria hyperborea* zoospores have a recorded dispersal range of ca 200 m (Fredriksen *et al.*, 1995). However, zoospore dispersal is greatly influenced by water movements, plus 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 nature of *Laminaria hyperborea* biotopes are partially reliant on low (or no) populations of sea urchins, primarily the species; *Echinus esculentus*, *Paracentrotus lividus* and *Strongylocentrotus droebachiensis*, which graze directly on macroalgae, epiphytes and the understory community. Multiple authors (Steneck *et al.*, 2002; Steneck *et al.*, 2004; Rinde & Sjøtun, 2005; Norderhaug & Christie, 2009; Smale *et al.*, 2013) have reported dense aggregations of sea urchins to be a principal threat to *Laminaria hyperborea* biotopes of the North Atlantic. Intense urchin grazing create expansive areas known as "urchin barrens", in which a shift can occur from *Laminaria hyperborea* dominated biotopes to those characterized by coralline encrusting algae, with a resultant reduction in biodiversity (Steneck *et al*., 2002, Norderhaug & Christie, 2009). Continued intensive urchin grazing pressure on *Laminaria hyperborea* biotopes can inhibit the *Laminaria hyperborea* recruitment (Sjøtun *et al*., 2006) and cause urchin barrens to persist for decades (Cristie *et al*., 1998; Stenneck *et al*., 2004; Rinde & Sjøtun, 2005). The mechanisms that control sea urchin aggregations are poorly understood but have been attributed to anthropogenic pressure on top down urchin predators (e.g. cod or lobsters). While these theories are largely unproven a number of studies have shown removal of urchins from grazed areas coincide with kelp re-colonization (Lienaas & Christie, 1996; Nourderhaug & Christie, 2009). Lienaas & Christie, (1996) removed *Strongylocentrotus droebachiensis* from "Urchin Barrens" and observed a succession effect, in which the substratum was initially colinized by filamentous macroalgae and *Saccharina latissima*, however after 2-4 years *Laminaria hyperborea* dominated the community.

Reports of large scale urchin barrens within the North East Atlantic are generally limited to regions of the North Norwegian and Russian Coast (Rinde & Sjøtun, 2005, Nourderhaug & Christie, 2009). Within the UK, urchin grazed biotopes (IR.MIR.KR.Lhyp.GzFt/Pk, IR.HIR.KFaR.LhypPar, IR.LIR.K.LhypSlat.Gz & IR.LIR.K.Slat.Gz) are generally localised to a few regions in North Scotland and Ireland (Smale *et al*., 2013; Stenneck *et al*., 2002; Norderhaug & Christie 2009; Connor *et al*., 2004). IR.MIR.KR.Lhyp.GzFt/Pk, IR.HIR.KFaR.LhypPar, IR.LIR.K.LhypSlat.Gz & IR.LIR.K.Slat.Gz are characterized by a canopy forming kelp. However, urchin grazing decreases the abundance and diversity of understory species. In the Isle of Man. Jones & Kain (1967) observed low *Echinus esculentus* grazing pressure can control the lower limit of *Laminaria hyperborea* and remove *Laminaria hyperborea* sporelings and juveniles. Urchin abundances in 'urchin barrens' have been reported as high as 100 individuals/$m^2$ (Lang & Mann, 1978). Kain (1967) reported urchin abundances of 1-4/$m^2$ within experimental plots of the Isle of Man. Therefore while 'urchin barrens' are not presently an issue within the UK, relatively low urchin grazing has been found to control the depth distribution of *Laminaria hyperborea*, negatively impact on *Laminaria hyperborea* recruitment and reduce the understory community abundance and diversity.

Other factors that are likely to influence the recovery of *Laminaria hyperborea* biotopes is competitive interactions with Invasive Non Indigenous Species (INIS), e.g. *Undaria pinnatifida* (Smale *et al*., 2013; Brodie *et al*., 2014; Heiser 2014), and/or the Lusitanian kelp *Laminaria ochroleuca* (Brodie *et al*., 2014; Smale *et al*., 2014). A predicted sea temperature rise in the North and Celtic seas of between 1.5-5°C over the next century (Philippart *et al*., 2011) is likely to create northward range shifts in many macroalgal species, including *Laminaria hyperborea. Laminaria hyperborea* is a northern (Boreal) kelp species, thus increases in seawater temperature is likely to affect the resilience and recoverability of *Laminaria hyperborea* biotopes with southerly distributions in the UK (Smale *et al*., 2013; Stenneck *et al*., 2002). Evidence suggests that the Lustanian kelp *Laminaria ochroleuca* (Smale *et al*., 2014), and the INIS *Undaria pinnatifida* (Heiser *et al*., 2014) are competing with *Laminaria hyperborea* along the UK south coast and may displace *Laminaria hyperborea* from some sub-tidal rocky reef habitats. The wider ecological consequences of *Laminaria hyperborea'* competition with *Laminaria ochroleuca* and *Undaria pinnatifida* are however as of yet unknown.

**Resilience assessment.** Sparse evidence is available to assess resilience of cape-form *Laminaria hyperborea* to the pressures assessed within this review. Svendsen & Kain (1971) suggests the cape-form is highly sensitive to physical disturbance and high siltation within IR.LIR.K.LhypCape could extend recovery of the habitat when compared to exposed *Laminaria hyperborea* biotopes (e.g. IR.HIR.KFaR.LhypR). Available evidence from exposed *Laminaria hyperborea* biotopes suggests that if cape-form *Laminaria hyperborea* were removed from the substratum, e.g. through physical disturbance, *Laminaria hyperborea* could re-establish dominance in the habitat within a period of 2-6 years (Kain 1975; Birkett *et al.*, 1998; Christie *et al.*, 1998), and the associated community within 7-10 years (Christie *et al.*, 1998). However, other factors such as competition interactions with *Laminaria ochroleuca* and *Undaria pinnatifida* may limit recovery of *Laminaria hyperborea* following disturbance. Also, urchin grazing pressure may negatively affect *Laminaria hyperborea* recruitment and reduce the diversity and abundance of the understory community. The resilience of IR.LIR.K.LhypCape has been assessed as **Medium**.

Heavy siltation could extend the recovery period of cape-forming *Laminaria hyperborea* however the effect of siltation on *Laminaria hyperborea* recovery is not directly quantified and therefore recovery rates from exposed *Laminaria hyperborea* biotopes has been used within this review. Urchin grazing pressure could extend recovery/resilience of the *Laminaria hyperborea* biotopes to over 25 years, if urchin grazing of the same scale as observed in Northern Norway occurred within the UK resilience would be re-assessed as Very Low. However, because of the limited/localised incidence of urchin grazing within the UK urchin grazing on large scales has not been included in this general resilience assessment. Introduction of Invasive Non Indigenous species (INIS) could also inhibit the recovery of *Laminaria hyperborea* biotopes for an indeterminate amount of time, in these cases resilience would need to be re-assessed as 'Very low'. Another factor that is beyond the scope of this sensitivity assessment is the presence of multiple concurrent synergistic or cumulative effects, which Smale *et al.* (2013) suggests could be more damaging than the individual pressures.

## Hydrological Pressures

| | Resistance | Resilience | Sensitivity |
|---|---|---|---|
| **Temperature increase (local)** | Medium<br>Q: Medium A: High C: High | Medium<br>Q: High A: High C: High | Medium<br>Q: Medium 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). However, above 17°C 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).

Subtidal red algae are less tolerant of temperature extremes than intertidal red algae, surviving between -2°C and 18-23°C (Lüning 1990; Kain & Norton, 1990). Temperature increase may affect growth, recruitment or interfere with reproduction processes. For example, there is some evidence to suggest that blade growth in *Delesseria sanguinea* is delayed until ambient sea temperatures fall below 13°C. Blade growth is also likely to be intrinsically linked to gametangia development (Kain, 1987), maintenance of sea temperatures above 13°C may affect recruitment success.

*IR.LIR.K.LhypCape is distributed along the west coast of the UK from Orkney to South West Ireland;*

*however records are concentrated in the North West of Scotland (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).

The available evidence suggests that combined with southern sea temperatures an increase of temperature of 5°C over a period of 1 month would not inhibit recruitment, however may be outside of the optimal range for spore production and/or settlement as well as negatively affect sporophyte growth. An increase in 2°C over a period of a year may similarly negatively affect *Laminaria hyperborea* recruitment processes in southern biotopes. Northern examples of *IR.LIR.K.LhypCape (where most records are concentrated) are unlikely to be affected at the benchmark level.*

**Sensitivity assessment.** Overall, a chronic change (2°C for a year) outside normal range for a year may reduce recruitment and growth, resulting in a minor loss in the population of kelp, especially in winter months or in southern examples of the biotope. However, an acute change (5°C for a month; e.g. from thermal effluent) may result in loss of abundance of kelp or extent of the bed, especially in winter. Therefore, resistance to the pressure is considered '**Medium**', and resilience '**Medium**'. The sensitivity of this biotope to increases in temperature has been assessed as '**Medium**'.

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

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). Subtidal red algae can survive at temperatures between -2°C and 18-23°C (Lüning, 1990; Kain & Norton, 1990).

*Laminaria hyperborea* is a boreal/northern species with a geographic range from mid Portugal to northern Norway (Birket *et al*., 1998), and a mid range within southern Norway (60°-65° North) (Kain, 1971). The average seawater temperature for southern Norway in October is 12-13°C (Miller *et al*., 2009), and average annual sea temperature, from 1970-2014, is 8°C (Beszczynska-Möller & Dye, 2013). The available information suggests that *Laminaria hyperborea* and habitat structure would not be affected, and may benefit from a water temperature decrease of 5°C over a month or 2°C for one year.

**Sensitivity assessment.** Resistance to the pressure is considered '**High**', and resilience '**High**'. The sensitivity of this biotope to decreases in temperature has been assessed as '**Not Sensitive**'.

| | | | |
|---|---|---|---|
| **Salinity increase (local)** | Low<br>Q: Low A: NR C: NR | Medium<br>Q: Low A: NR C: NR | Medium<br>Q: Low A: NR 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 (MNCR category 'Full' salinity) and growth rates are likely to be affected by periodic salinity stress. Birkett *et al.* (1998) suggests 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.

**Sensitivity assessment.** Resistance to the pressure is considered '**Low**', and resilience '**Medium**'. The sensitivity of this biotope to an increase in salinity has been assessed as '**Medium**'.

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

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 (MNCR category-Full Salinity) 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 and, therefore loss of this biotope.

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. A decrease in one MNCR salinity scale from Full Salinity (30-40psu) to Reduced Salinity (18-30 psu) would result in a decrease of *Laminaria hyperborea* sporophyte growth.

If salinity was returned to Full Salinity (30-40 psu) *Laminaria hyperborea* could out-compete *Saccharina latissma* and re-establish community dominance in 2-4 years (Kain, 1975; Leinaas & Christie, 1996), however full habitat structure may take over 10 years to recover (Birkett et al., 1998; Cristie *et al*., 1998). The ability of *Laminaria hyperborea* to out-compete *Undaria pinnatifida* within the UK is however unknown (Heiser *et al*., 2014), and as such interspecific interaction between *Laminaria hyperborea* and *Undaria pinnatifida* is not included within this sensitivity assessment.

**Sensitivity assessment**. Resistance to the pressure is considered '**Low**', and resilience '**Medium**'. The sensitivity of this biotope to decreases in salinity has been assessed as '**Medium**'.

| **Water flow (tidal current) changes (local)** | None<br>Q: Low A: NR C: NR | Medium<br>Q: High A: Medium C: High | Medium<br>Q: Low A: NR C: NR |
|---|---|---|---|

Cape-form *Laminaria hyperborea* (*Laminaria hyperborea f. cucullata*) is a growth form of *Laminaria hyperborea* found in extremely sheltered habitats, such as sea lochs. At a sheltered location in southern Norway, Svendsen & Kain (1971) transplanted six cape-form *Laminaria hyperborea* from 15 m Below Chart Datum (BCD) to 0.5 m BCD. After six months none of the cape-form *Laminaria hyperborea* had survived at 0.5m and only their holdfasts were still present. Svendsen & Kain (1971) noted whilst transporting the six cape-form *Laminaria hyperborea*, the cape-form fronds were very fragile and often ruptured under their own weight. Svendsen & Kain (1971) suggested increased wave action at 0.5 m was the reason why none of the cape-form *Laminaria hyperborea* survived beyond six months. Although the wave exposure at the site was not formally tested, this evidence suggests that cape-form *Laminaria hyperborea* is highly sensitive to physical disturbance e.g. from water movement (wave action and/or tidal movement).

**Sensitivity assessment**. IR.LIR.K.LhypCape occurs exclusively in tidal streams of <0.5 m/s. An increase in tidal streams >0.5 m may lead to significant mortality of cape-from *Laminaria hyperborea* and resultant loss of the characteristic species which defines this biotope. *Laminaria hyperborea* can however recover within a period of 2-4 years. Resistance to the pressure is considered '**None**', and resilience '**Medium**'. The sensitivity of this biotope to changes in peak mean spring bed velocity has been assessed as '**Medium**'.

| | | | |
|---|---|---|---|
| **Emergence regime changes** | None<br>Q: Low A: NR C: NR | Medium<br>Q: High A: Low C: High | Medium<br>Q: Low A: NR C: NR |

The upper limit of the *Laminaria hyperborea* bed is determined by wave action and water flow, desiccation, and competition from the emergence resistant *Laminaria digitata*. *Laminaria hyperborea* exposed at extreme low water are very intolerant of desiccation, the most noticeable effect being bleaching of the frond and subsequent death of the meristem and loss of the plant.

Cape-form *Laminaria hyperborea* (*Laminaria hyperborea f. cucullata*) is found from ca 4-25 m BCD (Svendsen & Kain, 1971; Connor *et al.*, 2004). Svendsen & Kain (1971) conducted a transplantation experiment to observe if cape-form fronds (of cape-form *Laminaria hyperborea*) were a phenotypic response of *Laminaria hyperborea* to low water movement. At a sheltered location in southern Norway, six cape-form *Laminaria hyperborea* were transplanted from 15 m Below Chart Datum (BCD) to 0.5 m BCD and ten *Laminaria hyperborea* vice versa. After six months none of the cape-form *Laminaria hyperborea* had survived at 0.5 m and only their holdfasts were still present. Of the ten *Laminaria hyperborea* transplanted to 15 m BCD, four survived and produced cape-form fronds. Svendsen & Kain (1971) noted whilst transporting the six cape-form *Laminaria hyperborea*, the cape-form fronds were very fragile and often ruptured under their own weight. Svendsen & Kain (1971) suggested increased wave action at 0.5 m was the reason why none of the cape-form *Laminaria hyperborea* survived beyond six months. Although the wave exposure at the site was not formally tested, this evidence suggests that cape-form *Laminaria hyperborea* is highly sensitive to physical disturbance e.g. from water movement (wave action and/or tidal movement).

**Sensitivity assessment.** Increased emergence is likely to lead to high mortality of *Laminaria hyperborea* through desiccation. Increased wave action in shallow water (0.5 m BCD) may also cause high mortality of shallow water example of the cape-form *Laminaria hyperborea* biotope. Resistance to the pressure is considered '**None**', and resilience '**Medium**'. The sensitivity of this biotope to changes in tidal emergence has been assessed as '**Medium**'.

| | | | |
|---|---|---|---|
| **Wave exposure changes (local)** | None<br>Q: Low A: NR C: NR | Medium<br>Q: High A: Medium C: High | Medium<br>Q: Low A: NR C: NR |

Cape-form *Laminaria hyperborea* (*Laminaria hyperborea f. cucullata*) is a growth form of *Laminaria hyperborea* found in extremely sheltered habitats, such as Scottish sea lochs or Irish sea loughs. Cape-form *Laminaria hyperborea* (*Laminaria hyperborea f. cucullata*) is a growth form of *Laminaria hyperborea* found in extremely sheltered habitats, such as sea lochs. At a sheltered location in southern Norway, Svendsen & Kain (1971) transplanted six cape-form *Laminaria hyperborea* from 15 m Below Chart Datum (BCD) to 0.5 m BCD. After six months none of the cape-form *Laminaria hyperborea* had survived at 0.5 m and only their holdfasts were still present. Svendsen & Kain (1971) noted whilst transporting the six cape-form *Laminaria hyperborea*, the cape-form fronds were very fragile and often ruptured under their own weight. Svendsen & Kain (1971) suggested increased wave action at 0.5 m was the reason why none of the cape-form *Laminaria hyperborea* survived beyond six months. Although the wave exposure at the site was not formally tested, this evidence suggests that cape-form *Laminaria hyperborea* is highly sensitive to physical disturbance e.g. from water movement (wave action and/or tidal movement).

Svendsen & Kain (1971) suggested that the cape-form *Laminaria hyperborea* was highly sensitive to physical disturbance, e.g. from water movement. IR.LIR.K.LhypCape occurs exclusively within sheltered-extremely wave sheltered sites. Sheltered sites have a maximum wind fetch of 20 km, and typically experience negligible wave exposure (Connor *et al.*, 2004). At sheltered sites, which experience higher wave exposure than extremely sheltered sites, cape-form *Laminaria hyperborea* can still persist but not in shallow water (<6 m, Svendsen & Kain 1971). An increase in nearshore significant wave height may therefore lead to significant mortality of cape-from *Laminaria hyperborea* in shallow water (0-5 m BCD) and therefore dramatically change the biotope structure of IR.LIR.K.LhypCape.

**Sensitivity assessment.** Resilience of IR.LIR.K.LhypCape to changes in wave height is based on *Laminaria hyperborea* recovery following commercial harvesting and information on life history traits (see resilience section for evidence base). Resistance to the pressure is considered '**None**', and resilience '**Medium**'. The sensitivity of this biotope to changes in peak mean spring bed velocity has been assessed as '**Medium**'.

## Chemical Pressures

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

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

Bryan (1984) suggested that the general order for heavy metal toxicity in seaweeds is: Organic Hg > inorganic Hg > Cu > Ag > Zn > Cd > Pb. Cole *et 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.

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

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

*Laminaria hyperborea* fronds, being almost exclusively subtidal, would not come into contact with freshly released oil, but only to sinking emulsified oil and oil adsorbed onto particles (Birket *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 forest. Similarly, surveys of subtidal communities at a number sites between 1 -22.5 m below chart datum, including *Laminaria hyperborea* 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. Overall the red algae are likely to be highly intolerant to hydrocarbon contamination. 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.

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

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

O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of macrophytes to oil and dispersant contamination (see Smith, 1968). 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). *Laminaria hyperborea* survived within >55 m 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)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | No evidence (NEv)<br>Q: NR A: NR C: NR |

**No Evidence**

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

This pressure is **Not assessed**.

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

Reduced oxygen concentrations have been shown to 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 2 mg/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. However, small invertebrate epifauna may be lost, causing a reduction in species richness. Therefore a resistance of '**High**' is recorded. Resilience is likely to be '**High**', and the biotopes is probably '**Not sensitive**' at the benchmark level.

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

This biotope is considered to be '**Not sensitive**' at the pressure benchmark, that assumes compliance with good status as defined by the WFD.

Holt *et al.* (1995) suggest that *Laminaria hyperborea* may be tolerant of nutrient enrichment since healthy populations are found at ends of sublittoral 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).

Increased nutrients may result in phytoplankton blooms that increase turbidity (see above). Increased nutrients may favour sea urchins, e.g. *Echinus esculentus*, due their ability to absorb dissolved organics, and result in increased grazing pressure leading to loss of understorey epiflora/fauna, decreased kelp recruitment and possibly 'urchin barrens'. Therefore, although nutrients may not affect kelps directly, indirect effects such as turbidity, siltation and competition may significantly affect the structure of the biotope.

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

Holt *et al.* (1995) suggest that *Laminaria hyperborea* may be tolerant of organic enrichment since healthy populations are found at ends of sublittoral 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). Increase 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. Therefore, although nutrients may not affect kelps directly, indirect effects such as turbidity may significantly affect the structure of *Laminaria hyperborea* biotopes.

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

## Physical Pressures

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

All marine habitats and benthic species are considered to have a resistance of '**None**' to this pressure and to be unable to recover from a permanent loss of habitat (resilience is '**Very low'**). Sensitivity within the direct spatial footprint of this pressure is therefore '**High**'. Although no specific evidence is described confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

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

If rock substrata were replaced with sedimentary substrata this would represent a fundamental change in habitat type, which *Laminaria hyperborea* would not be able to tolerate (Birket *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)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

**Not relevant** to bedrock biotopes.

| | | | |
|---|---|---|---|
| **Habitat structure changes - removal of substratum (extraction)** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

The species characterizing this biotope are epifauna or epiflora occurring on rock 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<br>Q: Low A: NR C: NR | Medium<br>Q: High A: Medium C: High | Medium<br>Q: Low A: NR C: NR |

Svendsen & Kain (1971) conducted a transplantation experiment to observe if cape-form fronds (of cape-form *Laminaria hyperborea*) were a phenotypic response of *Laminaria hyperborea* to low water movement. At a sheltered location in southern Norway, six cape-form *Laminaria hyperborea* were transplanted from 15 m below Chart Datum (BCD) to 0.5 m BCD and ten *Laminaria hyperborea* vice versa. After six months none of the cape-form *Laminaria hyperborea* had survived at 0.5 m and only their holdfasts were still present. Of the ten *Laminaria hyperborea* transplanted to 15 m BCD, four survived and produced cape-form fronds. Svendsen & Kain (1971) noted whilst transporting the six cape-form *Laminaria hyperborea*, the cape-form fronds were very fragile and often ruptured under their own weight. Svendsen & Kain (1971) therefore indicates that cape-form *Laminaria hyperborea* would be highly sensitive to abrasion.

Resilience of IR.LIR.K.LhypCape to abrasion is based on *Laminaria hyperborea* recovery following commercial harvesting and information on life history traits (see resilience section for evidence base).

**Sensitivity assessment.** The cape form of *Laminaria hyperborea* is particularly fragile and susceptible to physical disturbance (Svendsen & Kain, 1971). Loss of this distinctive characterizing species would result in loss of the biotope. Therefore resistance to the pressure is considered '**None**', and resilience '**Medium**'. The sensitivity of this biotope to damage to seabed surface features is assessed as '**Medium**'.

| | | | |
|---|---|---|---|
| **Penetration or disturbance of the substratum subsurface** | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

**Not Relevant**, please refer to pressure 'Abrasion/disturbance of the substratum on the surface of the seabed'.

| | | | |
|---|---|---|---|
| **Changes in suspended solids (water clarity)** | None<br>Q: High A: High C: High | Medium<br>Q: High A: High C: High | Medium<br>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 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 *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, as this biotope occurs in the vicinty of sediments and is already silted, the dominant kelp species will probably suffer a significant decline and resistance to this pressure is assessed as '**None**'. 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)** | High<br>Q: Medium A: Low C: Low | High<br>Q: High A: Low C: High | Not sensitive<br>Q: Medium A: Low C: Low |

Smothering by sediment e.g. 5 cm material during a discrete event, is unlikely to directly damage cape-form *Laminaria hyperborea* plants but inundation of sediment is likely to provide a barrier which may inhibit zoospore settlement and affect gametophyte survival (Birkett *et al*., 1998). Given the microscopic size of the gametophyte, 5 cm of sediment could be expected to significantly inhibit growth. Laboratory studies showed that *Laminaria hyperborea* gametophytes survived 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). IR.LIR.K.LhypCape is generally typified by low water movement (low wave and tidal exposure) and often found in close proximity to silted or muddy biotopes e.g. CR.LCR.BrAs.AmenCio and SS.SMu.CSaMu.VirOphPmax (Connor *et al*., 2004). Deposited sediments may therefore be retained within the resident habitat for numerous tidal cycles, and could affect kelp recruitment and the survival of the understory community (Birkett *et al*., 1998). *Laminaria hyperborea* can live for greater than 10 years (Pederson *et al*., 2012) and is therefore likely to persist following 'Light' deposition of up to 5 cm of fine material added to the seabed in a single, discrete event, however *Laminaria hyperborea* recruitment processes may be negatively affected and the understory community be denuded until the sediment is cleared. Following clearance of deposited sediment *Laminaria hyperborea* populations and the understory communities are expected to recover quickly.

**Sensitivity assessment.** Resistance to the pressure is considered '**High**', and resilience '**High**'. The sensitivity of this biotope to light deposition of up to 5cm of fine material added to the seabed in a single discreet event is assessed as '**Low**'.

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

Cape-form *Laminaria hyperborea* stipe is described as short, normally less than 50cm long (Svendsen & Kain 1971). Smothering by sediment e.g. 30 cm material during a discrete event, may inundate entire plants for extended periods and cause mortality of *Laminaria hyperborea*. Heavy deposition would also provide a barrier which may inhibit zoospore settlement and affect gametophyte survival (Birkett *et al.*, 1998). Given the microscopic size of the gametophyte, 30 cm of sediment could be expected to significantly inhibit growth. Laboratory studies showed that *Laminaria hyperborea* gametophytes survived 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).The understory epifauna/flora may be adversely affected, e.g. suspension or filter feeding fauna and/or algal species. If clearance of deposited sediment occurs rapidly then understory communities are expected to recover quickly.

Due to the short length of cape-form *Laminaria hyperborea* stipes (normally <50 cm) a large number of plants may be inundated by a 'heavy' deposition of up to 30 cm of fine material added to the seabed in a single discrete event. Inundation is also likely to smother the understory red seaweed and faunal community plus inhibt *Laminaria hyperborea* photosynthesis and respiration. IR.LIR.K.LhypCape is a low energy habitat in which deposited sediments are likely to remain within the habitat for numerous tidal cycles. Once the sediment is removed however *Laminaria hyperborea* has been shown to recover within 2-6 years (Kain, 1975; Lienaas & Christie, 1996). The associated understory community of red seaweeds is expected to recover relatively quickly.

**Sensitivity assessment.** Resistance to the pressure is considered '**Low**', and resilience '**Medium**'. The sensitivity of this biotope to heavy deposition of up to 30 cm of fine material added to the seabed in a single discreet event is assessed as '**Medium**'.

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

**Not assessed**. There is no evidence to suggest that litter would affect *Laminaria hyperborea* or associated habitats.

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

No evidence

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

Macroalgae have no hearing perception but vibrations may cause an impact, however no studies exist to support an assessment. Sensitivity has been assessed as '**No evidence'**.

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

There is no evidence to suggest that anthropogenic light sources would affect *Laminaria hyperborea*. 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)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR | Not relevant (NR)<br>Q: NR A: NR C: NR |

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

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

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

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

**Not relevant**

## Biological Pressures

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

**No evidence** regarding the genetic modification or effects of translocation of native populations was found.

| | | | |
|---|---|---|---|
| **Introduction or spread of invasive non-indigenous species** | Low<br>Q: High A: High C: High | Very Low<br>Q: High A: High C: High | High<br>Q: High A: High C: High |

*Undaria pinnatifida* has received a large amount of research attention as a major Invasive Non Indigenous Species (INIS) which could out-compete native UK kelp habitats (see Farrell & Fletcher, 2006; Thompson & Schiel, 2012, Brodie *et al*., 2014; Hieser *et al*., 2014). *Undaria pinnatifida* was first recorded in the UK, Hamble Estuary, in June 1994 (Fletcher & Manfredi, 1995) and has since spread to a number of British ports. *Undaria pinnatifida* is an annual species, sporophytes appear in Autumn and grow rapidly throughout winter and spring during which they can reach a length of 1.65 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*, *Saccorhiza polyschides* or *Desmarestia spp*., 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* (Farrell & Fletcher, 2006) and *Laminaria hyperborea* (Hieser *et al*., 2014).

In New Zealand, Thompson & Schiel (2012) observed that native fucoids could out-compete

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

**Sensitivity assessment**. Resistance to the pressure is considered '**Low**', and resilience '**Very low**'. The sensitivity of this biotope to introduction of invasive non-indigenous species is assessed as '**High**'.

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

Galls on the blade of *Laminaria hyperborea* and spot disease are associated with the endophyte *Streblonema* sp. although the causal agent is unknown (bacteria, virus or endophyte). Resultant damage to the blade and stipe may increase losses in storms. The endophyte inhibits spore production and therefore recruitment and recoverability (Lein *et al.*, 1991).

**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** | None<br>Q: Low A: NR C: NR | Medium<br>Q: Medium A: High C: High | Medium<br>Q: Low A: NR C: NR |

At the time of writing no evidence could be found on harvesting of cape-form *Laminaria hyperborea*. As noted by Sjøtun *et al.* (1998) cape form *Laminaria hyperborea* plants, on average, have a lower biomass than *Laminaria hyperborea* from exposed habitats (e.g. IR.HIR.Kfra.LhypR), and is therefore unlikely to be of the same commercial value. Svendsen & Kain (1971) conducted a transplantation experiment to observe if cape-form fronds (of cape-form *Laminaria hyperborea*) were a phenotypic response of *Laminaria hyperborea* to low water movement. At a sheltered location in southern Norway, six cape-form *Laminaria hyperborea* were transplanted from 15 m below Chart Datum (BCD) to 0.5 m BCD and ten *Laminaria hyperborea* vice versa. After six months none of the cape-form *Laminaria hyperborea* had survived at 0.5 m and only their holdfasts were still present. Of the ten *Laminaria hyperborea* transplanted to 15 m BCD, four survived and produced cape-form fronds. Svendsen & Kain (1971) noted whilst transporting the six cape-form *Laminaria hyperborea*, the cape-form fronds were very fragile and often ruptured under their own weight. Cape-form *Laminaria hyperborea* is therefore thought to be extremely fragile and brittle, physical disturbance of any nature is likely to result in mortality.

A number of review and experimental publications have assessed the recovery of *Laminaria hyperborea* beds and the associated community within high energy habitats. If environmental conditions are favourable *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 observations of discrete kelp harvesting events, 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*. Lienaas & Christie (1996) also observed *Laminaria hyperborea* re-colonization of 'urchin barrens', following removal of urchins. The substratum was initially colonized by filamentous macroalgae and *Saccharina latissima* however after 2-4 years *Laminaria hyperborea* dominated the community.

**Sensitivity assessment**. Targeted removal of kelp from this biotope is likely to result in loss of the biotope. Resistance to the pressure is considered '**None**'. However, the resilience is assessed as '**Medium**' and the sensitivity of this biotope is considered to be '**Medium**'.

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

At the time of writing no evidence could be found on harvesting (incidental or intentional trawling) of cape-form *Laminaria hyperborea*. As noted by Sjøtun *et al.*, (1998) cape form *Laminaria hyperborea* plants, on average, have a lower biomass than *Laminaria hyperborea* from exposed habitats (e.g. IR.HIR.Kfra.LhypR), and is therefore unlikely to be of the same value. *Laminaria hyperborea* cape form is highly sensitive to any physical disturbance. Incidental/accidental removal of cape-form *Laminaria hyperborea* as a result of other fisheries e.g. *Pectin maximus* collection within SS.SMu.CSaMu.VirOphPmax which is often in close proximity to IR.LIR.K.LhypCape (Connor *et al.*, 2004), is likely to cause similar effects to that of direct harvesting; as such the same evidence has been used for both pressure assessments.

Cape-form *Laminaria hyperborea* (*Laminaria hyperborea f. cucullata*) is a growth form of *Laminaria hyperborea* found in extremely sheltered habitats, such as Scottish sea lochs or Irish Sea Loughs. Svendsen & Kain (1971) conducted a transplant experiment between *Laminaria hyperborea* and cape-form *Laminaria hyperborea*. 100% mortality of cape-form *Laminaria hyperborea* was suggested to be a result of increased wave exposure at the transplanted site. Furthermore in transit to the host site, cape-form *Laminaria hyperborea* was noted to be extremely brittle and fronds often ruptured under their own weight. Cape-form *Laminaria hyperborea* is therefore thought to be extremely fragile and brittle, physical disturbance of any nature is likely to result in mortality.

A number of review and experimental publications have assessed the recovery of *Laminaria hyperborea* beds and the associated community within high energy habitats. If environmental conditions are favourable *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 observations of discrete kelp harvesting events, 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*. Lienaas & Christie (1996) also observed *Laminaria hyperborea* re-colonization of ‘urchin barrens’, following removal of urchins. The substratum was initially colinized by filamentous macroalgae and *Saccharina latissima* however after 2-4 years *Laminaria hyperborea* dominated the community.

**Sensitivity assessment**. Resistance to the pressure is considered ‘**None**’, and resilience ‘**Medium**’. Sensitivityhas been assessed as ‘**Medium**’.

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