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Grazed *Laminaria hyperborea* park with coralline crusts on lower infralittoral rock

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

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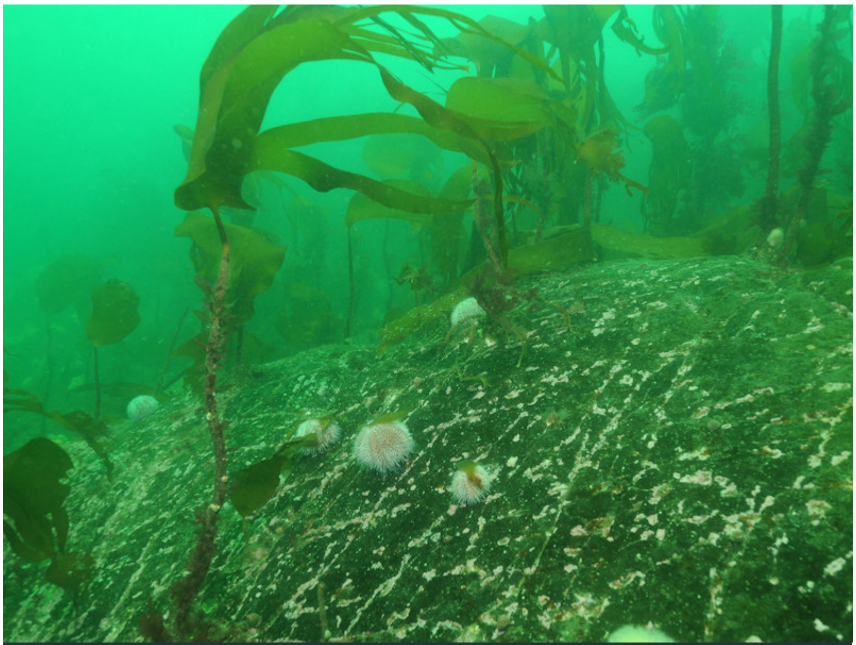

Grazed *Laminaria hyperborea* park with coralline crusts on lower infralittoral rock
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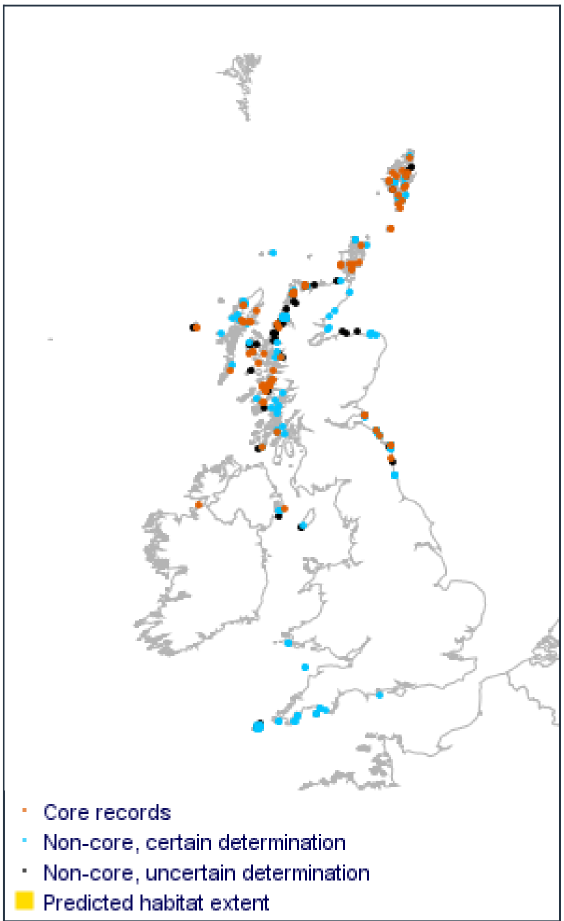

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Thomas Stamp **Refereed by** This information is not refereed.

Summary

UK and Ireland classification

EUNIS 2008	A3.2144	Grazed *Laminaria hyperborea* park with coralline crusts on lower infralittoral rock
JNCC 2015	IR.MIR.KR.Lhyp.GzPk	Grazed *Laminaria hyperborea* park with coralline crusts on lower infralittoral rock
JNCC 2004	IR.MIR.KR.Lhyp.GzPk	Grazed *Laminaria hyperborea* park with coralline crusts on lower infralittoral rock
1997 Biotope	IR.MIR.GzK.LhypGz.Pk	Grazed *Laminaria hyperborea* park with coralline crusts on lower infralittoral rock

Description

Exposed and moderately exposed kelp park in some areas is heavily grazed by the urchin *Echinus esculentus*. The rock surface lacks any significant turf of foliose seaweeds and generally looks bare, though it is covered by coralline algal crusts and some grazing-resistant species such as the keel worm *Spirobranchus triqueter*. The kelp stipes may or may not be grazed; in the most extremely grazed areas, they too are devoid of epiphytic seaweeds. More usually, however, the stipes offer a refuge from grazing, and are characterized by dense turfs of red seaweeds, especially *Phycodrys rubens*, *Palmaria palmata*, *Membranoptera alata* and *Delesseria sanguinea*. The fauna within a grazed kelp park is also relatively sparse, though some species will survive in cracks and crevices, or other areas that are protected from grazing. This biotope generally occurs below a grazed kelp forest (MIR.LhypGz.Ft).

Depth range

10-20 m

Additional information

-

Listed By

- none -

Further information sources

Search on:

JNCC

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

IR.MIR.KR.Lhyp.GzFt/pk are defined by the kelp *Laminaria hyperborea* which is grazed to varying extends by the urchin *Echinus esculentus.* At high densities *Laminaria hyperborea* forms a canopy over infralittoral rock. Beneath the canopy an understory community grows, typically defined by a red seaweed turf although faunal species dominate in tide swept and/or wave surged conditions. Grazing by the urchins; Echinus esculentus and Paracentrotus lividus can also define the biotope and reduce the biomass of *Laminaria hyperborea* and understory flora. The abundance of *Laminaria hyperborea* is determined by light availability, which decreases with an increase in water depth. Therefore, depth and water clarity determines the density of Laminaria and hence the distribution of kelp forest (high density kelp) and park (low density kelp) sub-biotopes.

Kelp biotopes are a major source of primary productivity, and support magnified secondary productivity within North Atlantic coastal waters (Smale *et al*., 2013, Brodie *et al*., 2014). In Scotland alone kelp biotopes are estimated to cover 8000km2 (Walker, 1953), and account for ca 45% of primary production in UK coastal waters (Smale *et al*., 2013). Therefore kelp biotopes, of which *Laminaria hyperborea* is dominant within UK sub-tidal rocky reefs (Birkett *et al*., 1998), make a substantial contribution to coastal primary production in the UK (Smale *et al*., 2013). *Laminaria hyperborea* is grazed directly by species such as Patella pellucida, however approximately 80% of primary production is consumed as detritus or dissolved organic material (Krumhansl, 2012) which is both retained within and transported out of the parent kelp forest, providing valuable nutrition to potentially low productivity habitats such as sandy beaches (Smale *et al*., 2013).

Laminaria hyperborea also acts as an ecosystem engineer (Jones *et al*., 1996; Smale *et al*., 2013) by altering; light levels (Sjøtun *et al*., 2006), physical disturbance (Connell, 2003), sedimentation rates (Eckman *et al*., 1989) and water flow (Smale *et al*., 2013), profoundly altering the physical environment for fauna and flora in close proximity. *Laminaria hyperborea* biotopes increase the three dimensional complexity of unvegetated rock (Norderhaug, 2004, Norderhaug *et al*., 2007, Norderhaug & Christie, 2011, Gorman *et al*., 2012; Smale *et al*., 2013) and support high local diversity, abundance and biomass of epi/benthic species (Smale *et al*., 2013), and serve as a nursery ground for a number of commercial important species, e.g. Gadidae (The taxonomic family that contains many commercially important marine fish species, including the Atlantic Cod and Pollack) (Rinde *et al*., 1992).

In undertaking this assessment of sensitivity, account is taken of knowledge of the biology of all characterizing species/taxa in the biotope. For this sensitivity assessment *Echinus esculentus* and *Laminaria hyperborea* are the primary focus of research, however it is recognized that the understory community, typically red seaweeds, also define the biotope. Examples of important species groups are mentioned where appropriate.

Resilience and recovery rates of habitat

A number of review and experimental publications have assessed the recovery of *Laminaria hyperborea* kelp beds and the associated community. 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*., 1998b; 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). These recovery rates were based on 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* (Fletcher *et al.*, 2006).

In south Norway, *Laminaria hyperborea* forests are harvested, which results in large scale removal of the canopy forming kelps. Cristie *et al.*, (1998) found that in south Norwegian *Laminaria hyperborea* beds a pool of small (<25cm) understory *Laminaria hyperborea* plants persist beneath the kelp canopy for several years. The understory *Laminaria hyperborea* sporophytes had fully re-established the canopy at a height of 1m within 2-6 years after kelp harvesting. Within 1 year following harvesting, and each successive year thereafter, a pool of *Laminaria hyperborea* recruits had re-established within the understory beneath the kelp canopy. Cristie *et al.*, (1998) suggested that *Laminaria hyperborea* bed re-establishment from understory recruits (see above) inhibits the colonization of other kelps species and furthers the dominance of *Laminaria hyperborea* within suitable habitats, stating that *Laminaria hyperborea* habitats are relatively resilient to disturbance events.

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 ~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).

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 creates 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 (Lienaas & Christie, 1996; 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 colonized 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* in the and remove *Laminaria hyperborea* sporelings and juveniles. Urchin abundances in 'urchin barrens' have been reported as high as 100 individuals/m^2 (Lang & Mann, 1976). 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.

Echinus esculentus is a sea urchin found within Northeast Atlantic, recorded from Murmansk Coast, Russia to Portugal (Hansson, 1998). *Echinus esculentus*, along with other urchins, is an important algal grazer in the North East Atlantic. (Connor *et al*., 2004). *Echinus esculentus* is estimated to have a lifespan of 8-16 years (Nichols, 1979; Gage, 1992) and reach sexual maturity within 1-3 years (Tyler-Walters, 2008). Maximum spawning occurs in spring although individuals may spawn over a protracted period throughout the year. Gonad weight is at it's maximum in February/March in English Channel (Comely & Ansell, 1989) but decreases during spawning in spring and then increases again through summer and winter until the next spawning season. Spawning occurs just before the seasonal rise in temperature in temperate zones but is probably not triggered by rising temperature (Bishop, 1985). *Echinus esculentus* is a broadcast spawner, with a complex larval life history which includes a blastula, gastrula and a characteristic 4 armed echinopluteus stage that forms an important component of the zooplankton. MacBride (1914) observed planktonic larval development could take 45-60 days in captivity. Recruitment is sporadic or variable depending on locality, e.g. Millport populations showed annual recruitment, whereas few recruits were found in Plymouth populations during Nichols studies between 1980-1981 (Nichols, 1984). Bishop & Earll (1984) suggested that the population of *Echinus esculentus* at St Abbs had a high density and recruited regularly whereas the Skomer population was sparse, ageing and had probably not successfully recruited larvae in the previous 6 years (Bishop & Earll, 1984). Comely & Ansell (1988) noted that the largest number of *Echinus esculentus* occurred below the kelp forest.

Echinus esculentus is a mobile species (Tyler-Walters, 2008) and could therefore migrate and re-populate an area quickly if removed. For example, Lewis & Nichols (1979) found that adults were able to colonize an artificial reef in small numbers within 3 months and the population steadily grew over the following year. If completely removed from a site and local populations are naturally sparse then recruitment may be dependent on larval supply which can be highly variable. As suggested by Bishop & Earll (1984) the Skomer, Wales *Echinus esculentus* population had most likely not successfully recruited for 6 years which would suggest the mature population would be highly sensitive to removal and may not return for several years. On 19th November 2002 the *Prestige* oil tanker spilled 63 000t of fuel 130 nautical miles off Galicia, Spain. High wave exposure and strong weather systems increased mixing of the oil to 'some' depth within the water column, causing sensitive faunal communities to be effected. Preceding and for nine years following the oil spill, the biological community of Guéthary, France was monitored. Following the oil spill taxonomic richness decreased significantly from 57 recorded species to 41, which included the loss of *Echinus esculentus* from the site. 2-3 years after the oil spill taxonomic richness had increased to pre-spill levels and *Echinus esculentus* had returned (Castège *et al.*, 2014).

Resilience assessment. The evidence suggests that beds of mature *Laminaria hyperborea* can regenerate from disturbance within a period of 1-6 years, and the associated community within 7-10 years. However, other factors such as competitive interactions with *Laminaria ochroleuca* and *Undaria pinnatifida* may limit recovery of *Laminaria hyperborea* biotopes following disturbance. The recovery of *Laminaria hyperborea* biotopes to disturbance from commercial harvesting in south Norway suggests that *Laminaria hyperborea* beds and the associated community could recover from a significant loss of canopy cover within 10 years. *Echinus esculentus* can reportedly reach sexual maturity within 1-2 years (Tyler-Walters, 2008), however as highlighted by Bishop & Earll (1984) and Castège *et al.*, (2014) recovery may take 2-6 years (possibly more if local recruitment is poor). Resilience has therefore been assessed as **Medium**.

Please note* as in Northern Norway urchin grazing pressure could extend recovery/resilience of the *Laminaria hyperborea* biotopes >25 years, If intensive urchin grazing (as seen in Northern Norway) occurs in 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 (as in Northern Norway) has not been included in this general resilience assessment. Introduction of Invasive Non Indigenous Species (INIS) will 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 a more damaging than the individual pressures.

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	Medium Q: High A: High C: High	Medium Q: High A: High C: High	Medium 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.*, 1988b). 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*., 1998b).

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), and maintenance of sea temperatures above 13 °C may affect recruitment success.

Increases in sea temperature are also likely to create a northward range contraction of *Laminaria hyperborea* (Brodie *et al*., 2014), and may inhibit competitive ability at the southern edge of *Laminaria hyperborea'* range. *Laminaria hyperborea* may be out-competed by the Invasive Non Indigenous Species (INIS) *Undaria pinnatifida* (Brodie *et al*., 2014; Heiser *et al*., 2014) and/or its' Lusitanian competitor-*Laminaria ochroleuca* (Smale *et al*., 2014) along the south coast of the UK (see sub-biotopes IR.HIR.KFaR.LhypR.Loch & IR.LIR.K.LhypLoch). The ecological impacts of such invasions could fundamentally alter *Laminaria hyperborea* habitat structure and limit recovery, however at the time of writing these effects are largely unknown (Brodie *et al*., 2014; Smale *et al*., 2014).

Bishop (1985) suggested that *Echinus esculentus* cannot tolerate high temperatures for prolonged periods due to increased respiration rate and resultant metabolic stress. Ursin (1960) reported *Echinus esculentus* occurred at temperatures between 0-18°C in Limfjord, Denmark. Bishop (1985) noted that gametogenesis occurred at 11-19°C however, continued exposure to 19°C disrupted gametogenesis. Embryos and larvae developed abnormally after 24hr exposure to 15°C but normally at 4, 7 and 11°C (Tyler & Young 1998).

Sensitivity assessment. This biotope 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). Overall, a chronic change (2°C for a year) outside normal range for a year may reduce *Laminaria hyperborea* 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. An increase in sea surface temperature of 2°C for a period of 1 year combined with high temperatures may approach the upper temperature threshold of *Echinus esculentus.* 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 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 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).

Echinus esculentus has been recorded from the Murmansk Coast, Russia. Due to the high latitude at which *Echinus esculentus* can occur it is unlikely to be affected at the pressure benchmark.

Sensitivity assessment. This biotope 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). The available information suggests the key characterizing species of this biotope would not be affected. 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 Q: Low A: NR C: NR	Medium Q: High A: Medium C: High	Medium 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) 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.

Echinoderms are generally stenohaline and possess no osmoregulatory organ (Boolootian, 1966). Therefore an increase in salinity may cause *Echinus esculentus* mortality. *Alcyonium digitatum*' distribution and the depth at which it occurs also suggest it would not likely experience regular salinity fluctuations and therefore not tolerate significant increases in salinity

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 Q: Medium A: Medium C: Medium	Medium Q: High A: Medium C: High	Medium Q: Medium A: Medium 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.

Echinoderms are generally unable to tolerate low salinity (stenohaline) and possess no osmoregulatory organ (Boolootian, 1966). At low salinity urchins gain weight, and the epidermis loses its pigment as patches are destroyed; prolonged exposure is fatal. However, within *Echinus* *esculentus* there is some evidence to suggest intracellular regulation of osmotic pressure due to increased amino acid concentrations. Furthermore as highlighted the Marine Nature Conservation Review (MNCR) records of 23rd Oct 2014 show *Echinus esculentus* is found within a number of variable and reduced salinity biotopes, e.g. IR.LIR.KVS.SlatPsaVS.

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)	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. Maximal significant wave height (Hm0) was 3.67 & 2m at the exposed and sheltered sites, and maximal water velocity (Velrms) was 0.6 & 0.3m/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.

Biotope structure is however different between wave exposed and sheltered sites. Pederson *et al.* (2012) observed *Laminaria hyperborea* biomass, productivity and density increased with an increase in wave exposure. At low wave exposure *Laminaria hyperborea* canopy forming plants were smaller, had lower densities and had higher mortality rates than at exposed sites. At low wave exposure Pederson *et al.* (2012) suggested that high epiphytic loading on *Laminaria hyperborea* impaired light conditions, nutrient uptake, and increased the drag on the host *Laminaria hyperborea* during extreme storm events.

The morphology of the stipe and blade of kelps vary with 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, 1998). In addition, the lamina becomes narrower and thinner in strong currents (Sjøtun & Fredriksen, 1995). However, the stipe of *Laminaria hyperborea* is relatively stiff and can snap in strong currents. *Laminaria hyperborea* is usually absent from areas of high wave action or strong currents, although it is found in the Menai Strait, Wales, where tidal velocities can exceed 4 m/s (NBN, 2015) and in tidal rapids in Norway (J. Jones, pers. comm.) *Laminaria hyperborea* growth can persist in very strong tidal streams (>3 m/s).

Increase water flow rate may also remove or inhibit grazers including *Patella pellucida* and *Echinus esculentus* and remove epiphytic algae growth (Pederson *et al.*, 2012). The associated algal flora and suspension feeding faunal populations change significantly with different water flow regimes. Increased water flow rates may reduce the understorey epiflora, to be replaced by an epifauna dominated community (e.g. sponges, anemones and polyclinid ascidians) as in the biotope IR.HIR.KFaR.LhypFa. The composition of the holdfast fauna may also change, e.g. energetic or sheltered water movements favour different species of amphipods (Moore, 1985).

IR.HIR.KFaR.LhypR, IR.HIR.KFaR.LhypFa, IR.MIR.KR.Lhyp, and their associated sub-biotopes are found within strong (1.5-3 m/s)-moderate (0.5-1.5 m/s) tidal streams. A change in peak mean spring bed flow velocity which does not result in a change in tidal streams above or below 0.5-3 m/s is not likely to affect the dominance of *Laminaria hyperborea* within the community, but may cause changes in the understory community. The prominent understory filter feeding community within IR.HIR.KFaR.LhypFa is reliant on high water movement. A decrease in tidal streams may result in a decline of filter feeding fauna and an increase in red seaweeds within the understory community or vice versa with an increase in tidal streams

Echinus esculentus occurred in kelp beds on the west coast of Scotland in currents of about 0.5 m/sec. Outside the beds specimens were occasionally seen being rolled by the current (Comely & Ansell, 1988), which may have been up to 1.4 m/sec. Urchins are removed from the stipe of kelps by wave and current action. *Echinus esculentus* are also displaced by storm action. After disturbance *Echinus esculentus* migrates up the shore, an adaptation to being washed to deeper water by wave action (Lewis & Nichols, 1979). Therefore, increased water flow may remove the population from the affected area; probably to deeper water although individuals would probably not be killed in the process and could recolonize the area quickly.

Sensitivity assessment. A change in peak mean spring bed flow velocity of between 0.1m/s to 0.2m/s for more than 1 year is not likely to affect the dominance of *Laminaria* hyperborea, however subtle differences in tidal regime may influence the understory community. *Echinus esculentus* may become dislodged but are unlikely to be killed and may recolonize quickly Resistance to the pressure is considered ‘**High**’, and resilience ‘**High**’. Hence, the sensitivity of this biotope to changes in peak mean spring bed velocity has been assessed as ‘**Not Sensitive**’.

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

The upper limit of the *Laminaria hyperborea* bed is determined by wave action and water flow, desiccation, and competition from the more 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. An increase in wave exposure (see below- water flow), as a result of increased emergence, has been found to exclude *Laminaria hyperborea* from shallow waters due to dislodgement of the sporophyte or snapping of the stipe (Birket *et al*., 1998). Hence, an increase in emergence is likely to lead to mortality of exposed *Laminaria hyperborea* and the associated habitat.

An increase in water depth/decreased emergence (at the benchmark level) may increase the upper depth restriction of *Laminaria hyperborea* forest biotope variants. However, limited light availability at depth will decrease the lower extent of *Laminaria hyperborea*, and may therefore result in a shift from forest to park biotope variants at depth. Further increases in depth will cause a community shift to that characterized by circalittoral faunal species, however this is beyond the scope of the benchmark.

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 could re-establish further down the shore within a similar emergence regime to that which existed previously. Similarly, a decrease in emergence may allow the biotope to extend its extent up the shore, however, completion form other species would probably erode its lower extent.

Sensitivity assessment. Resistance to the pressure is considered ‘**Low**’, and resilience ‘**Medium**’. The sensitivity of this biotope to changes in tidal emergence has been assessed 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.

Biotope structure is however different between wave exposed and sheltered sites. Pederson *et al.*, (2012) observed *Laminaria hyperborea* biomass, productivity and density increased with an increase in wave exposure. At low wave exposure *Laminaria hyperborea* canopy forming plants were smaller, had lower densities and had higher mortality rates than at exposed sites. At low wave exposure high epiphytic loading on *Laminaria hyperborea* was theorised to impair light conditions, nutrient uptake, and increase the drag of the host *Laminaria hyperborea* during extreme storm events.

The morphology of the stipe and blade of kelps vary with 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, 1998). In addition, the lamina becomes narrower and thinner in strong currents (Sjøtun & Fredriksen, 1995). However, the stipe of *Laminaria hyperborea* is relatively stiff and can snap in strong currents. *Lamiaria hyperborea* is usually absent from areas of extreme wave action and can be replaced by *Alaria esculenta*. In extreme wave exposures *Alaria esculenta* can dominate the shallow sub-littoral to a depth of 15m (Birket *et al.*, 1998).

Increase water flow rate may also remove or inhibit grazers including *Patella pellucida* and *Echinus esculentus* and remove epiphytic algae growth (Pederson *et al.*, 2012). The associated algal flora and suspension feeding faunal populations change significantly with different water flow regimes. Increased water flow rates may reduce the understorey epiflora, to be replaced by an epifauna dominated community (e.g. sponges, anemones and polyclinid ascidians) as in the biotope IR.HIR.KFaR.LhypFa. The composition of the holdfast fauna may also change, e.g. energetic or sheltered water movements favour different species of amphipods (Moore, 1985).

IR.HIR.KFaR.LhypR, IR.HIR.KFaR.LhypFa, IR.MIR.KR.Lhyp, and their associated sub-biotopes are found between extremely exposed to moderate wave exposure. Changes in local wave height above or below that experienced in extremely exposed to moderately exposed sites will affect the dominance of *Laminaria hyperborea*. Smaller changes in local wave height have the potential to cause changes to the understory community. The prominent understory filter feeding community within IR.HIR.KFaR.LhypFa is reliant on wave surge currents. A decrease in wave surge may result in a decline of filter feeding fauna and an increase in red seaweeds within the understory community or vice versa.

Echinus esculentus occurred in kelp beds on the west coast of Scotland in currents of about 0.5 m/sec. Outside the beds specimens were occasionally seen being rolled by the current (Comely & Ansell, 1988), which may have been up to 1.4 m/sec. Urchins are removed from the stipe of kelps by wave and current action. *Echinus esculentus* are also displaced by storm action. After disturbance *Echinus esculentus* migrates up the shore, an adaptation to being washed to deeper water by wave action (Lewis & Nichols, 1979). Keith Hiscock (pers. comm.) reported *Echinus esculentus* occurred in significant numbers as shallow as 15m below low water at the extremely wave exposed site of Rockall, Scotland. Therefore, localised increases in wave height may remove the population from the affected area; probably to deeper water although individuals would probably not be killed in the process and could recolonize the area quickly.

Sensitivity assessment. A change in nearshore significant wave height >3% but <5% is however unlikely to have a significant effect. Resistance to the pressure is considered '**High**', and resilience '**High**'. Hence, the sensitivity of this biotope to changes in local wave height has been assessed as '**Not Sensitive**'.

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.

Little is known about the effects of heavy metals on echinoderms. Bryan (1984) reported that early work had shown that echinoderm larvae were sensitive to heavy metals contamination, for example Migliaccio *et al*. (2014) reported exposure of *Paracentrotus lividis* larvae to increased levels of cadmium and manganese caused abnormal larval development and skeletal malformations. Kinne (1984) reported developmental disturbances in *Echinus esculentus* exposed to waters containing 25 µg / l of copper (Cu).

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 fronds, being almost exclusively sub tidal, would not come into contact with freshly released oil, but only to sinking emulsified oil and oil adsorbed onto particles (Birket *et al*., 1998b). 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 1-22.5 m 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. 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.

Echinus esculentus is subtidal and unlikely to be directly exposed to oil spills. However, as with the *Prestige'* oil spill rough seas can cause mixing with the oil and the seawater, and therefore subtidal habitats can be affected by the oil spill. Castège *et al*., (2014) recorded the recovery of rocky shore communities following the *Prestige* oil spill which impacted the French Atlantic coast. Rough weather at the time of the spill increased mixing between the oil and seawater, causing sub-tidal communities/habitats to be affected. The urchin *Echinus esculentus* was reported absent after the oil spill however returned after 2-5 years. Large numbers of dead *Echinus esculentus* were found between 5.5 and 14.5 m in the vicinity of Sennen cove, presumably due to a combination of wave exposure and heavy spraying of dispersants following the '*Torrey canyon'* oil spill (Smith 1968). Smith (1968) also demonstrated that 0.5 -1ppm of the detergent BP1002 resulted in developmental abnormalities in its echinopluteus larvae. *Echinus esculentus* populations in the vicinity of an oil terminal in A Coruna Bay, Spain, showed developmental abnormalities in the skeleton. The tissues contained high levels of aliphatic hydrocarbons, naphthalenes, pesticides and heavy metals (Zn, Hg, Cd, Pb, and Cu) (Gomez & Miguez-Rodriguez 1999).

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). 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 >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.

Large numbers of dead *Echinus esculentus* were found between 5.5 and 14.5 m in the vicinity of Sennen, presumably due to a combination of wave exposure and heavy spraying of dispersants in that area following the *Torrey Canyon* oil spill (Smith 1968). Smith (1968) also demonstrated that 0.5 -1ppm of the detergent BP1002 resulted in developmental abnormalities in echinopluteus larvae of *Echinus esculentus*. *Echinus esculentus* populations in the vicinity of an oil terminal in A Coruna Bay, Spain, showed developmental abnormalities in the skeleton. The tissues contained high levels of aliphatic hydrocarbons, naphthalenes, pesticides and heavy metals (Zn, Hg, Cd, Pb, and Cu) (Gomez & Miguez-Rodriguez 1999).

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	Medium Q: High A: Medium C: High	High Q: High A: Medium C: High	Low Q: High 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). In addition, the biotope occurs in areas of moderate to extreme wave action, so is likely to be continuously aerated. 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).

In August 1978 a dense bloom of a dinoflagellate, *Gyrodinium aureolum* occurred surrounding Geer reef in Penzance Bay, Cornwall and persisted until September that year. Observations by local divers indicated a decrease in underwater visibility (<1 m) from below 8 m Below Sea Level. It was also noted that many of the faunal species appeared to be affected, e.g. no live *Echinus esculentus* were observed whereas on surveys prior to August were abundant, *Alcyonium sp*. and Bryozoans were also in an impoverished state. During follow up surveys conducted in early September *Alcyonium sp*. were noted to be much healthier and feeding. It was suggested the decay of

Gyrodinium aureolum either reduced oxygen levels or physically clogged faunal feeding mechanisms. Adjacent reefs where also surveyed during the same time period and the effects of the *Gyrodinium aureolum* bloom were less apparent. It was suggested that higher water agitation in shallow water on reefs more exposed to wave action were less effected by the phytoplankton bloom (Dennis, 1979).

Sensitivity Assessment. Reduced oxygen levels are likely to inhibit photosynthesis and respiration but not cause a loss of the macroalgae population directly. Furthermore wave exposure is likely to constantly aerate the affected area. While de-oxygenation may not directly affect *Laminaria hyperborea*, small invertebrate epifauna may be lost, causing a reduction in species richness. Therefore resistance has been assessed as '**Medium**' is recorded. Resilience is likely to be '**High**', and the biotopes is probably '**Low**' 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

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 water clarity pressure). 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.

It was suggested by Comely & Ansell (1988) that *Echinus esculentus* could absorb dissolved organic material for the purposes of nutrition. Nutrient enrichment may encourage the growth of ephemeral and epiphytic algae and therefore increase sea-urchin food availability. Lawrence (1975) reported that sea urchins had persisted over 13 years on barren grounds near sewage outfalls, presumably feeding on dissolved organic material, detritus, plankton and microalgae, although individuals died at an early age.

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

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 organic enrichment has also been found to increase the abundance and dominance of suspension feeding fauna within *Laminaria hyperborea* holdfasts (Sheppard *et al.*, 1980). 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 and the increased abundance of suspension feeding fauna may affect the structure of *Laminaria hyperborea* biotopes (se water clarity above).

It was suggested by Comely & Ansell (1988) that *Echinus esculentus* could absorb dissolved organic material for the purposes of nutrition. Organic enrichment may encourage the growth of ephemeral and epiphytic algae and therefore increase sea-urchin food availability. Lawrence (1975) reported that sea urchins had persisted over 13 years on barren grounds near sewage outfalls, presumably feeding on dissolved organic material, detritus, plankton and microalgae, although individuals died at an early age.

Sensitivity assessment. While organic enrichment may not have any direct effects on *Laminaria hyperborea*, increased turbidity and abundance of suspension feeding fauna may have significant effects on the biotope structure. Resistance to the pressure has therefore been 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 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 *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) 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	Low Q: High A: High C: High	Medium Q: High A: High C: High	Medium Q: High A: High C: High

Christie *et al.* (1998) observed *Laminaria hyperborea* habitat regeneration following commercial *Laminaria hyperborea* trawling in south Norway. Within the study area, trawling removed all large canopy-forming adult *Laminaria hyperborea*, however sub-canopy recruits were largely unaffected. In 2-6 years of harvesting a new canopy had formed 1m off the seabed. The associated holdfast communities recovered in 6 years, however the epiphytic stipe community did not fully recover within the same time period. Christie *et al.*, (1998) suggested that kelp habitats were relatively resistant to direct disturbance/removal of *Laminaria hyperborea* canopy.

Recurrent disturbance occurring at a smaller time scale than the recovery period of 2-6 years (stated above) could extend recovery time. 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* (Fletcher *et al.*, 2006). 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.

Species with fragile tests, such as *Echinus esculentus* were reported to suffer badly as a result of scallop or queen scallop dredging (Bradshaw et al., 2000; Hall-Spencer & Moore, 2000). Kaiser et al. (2000) reported that *Echinus esculentus* were less abundant in areas subject to high trawling disturbance in the Irish Sea. Jenkins *et al.* (2001) conducted experimental scallop trawling in the North Irish sea and recorded the damage caused to several conspicuous megafauna species, both when caught as bi-catch and when left on the seabed. The authors predicted 16.4% of *Echinus esculentus* were crushed/dead, 29.3% would have >50% spine loss/minor cracks, 1.1% would have <50% spine loss and the remaining 53.3% would be in good condition. Sea urchins can rapidly regenerate spines, e.g. *Psammechinus miliaris* were found to re-grow all spines within a period of 2 months (Hobson, 1930).

Sensitivity assessment. Resistance to the pressure is considered '**Low**', 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) 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" above.

Changes in suspended solids (water clarity)	None 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 subsurface 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 the depth range of *Laminaria hyperborea* (0-47m Below Sea Level) (Birket *et al*., 1998). Light penetration influences the maximum depth at which kelp species can grow and it has been reported that Laminarians grow at depths at which the light levels are reduced to 1 percent of incident light at the surface. Maximal depth distribution of laminarians, therefore, varies from 100 m in the Mediterranean to only 6-7 m in the silt-laden German Bight. In Atlantic European waters, the depth limit is typically 35 m. In very turbid waters the depth at which *Laminaria hyperborea* is found may be reduced to 2.5m (Birkett *et al*. 1998), or in some cases excluded completely (e.g. Severn Estuary), because of the alteration in light attenuation by suspended sediment (Birkett *et al*. 1998; 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 decrease *Laminaria hyperborea* abundance and density (see sub biotope-IR.HIR.KFaR.LhypR.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 sporophytes 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). An absence of this biotope in silt rich environments is therefore expected.

Moore (1977) suggested that *Echinus esculentus* was unaffected by turbid conditions. *Echinus esculentus* is an important grazer of red macro-algae within CR.MCR.EcCr. Increased turbidity and resultant reduced light penetration is likely to negatively affect algal growth. However, *Echinus esculentus* can feed on alternative prey, detritus or dissolved organic material (Lawrence, 1975, Comely & Ansell, 1988)

Sensitivity Assessment. *Echinus esculentus* is unlikely to be affected. However, an increase in water clarity from clear to intermediate (10-100mg/l) represent a change in light attenuation of ca 0.67-6.7 Kd/m, and is likely to result in a greater than 50% reduction in photosynthesis of Laminaria spp. Therefore, the dominant kelp species will probably suffer a severe decline, and the resistance to this pressure is assessed as '**None**'. Resilience to this pressure is probably '**Medium**' at the benchmark. Hence, this biotope is regarded as having a sensitivity of '**Medium** 'to this pressure.

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

Smothering by sediment e.g. 5 cm material during a discrete event, is unlikely to damage *Laminaria hyperborea* sporophytes but is likely to affect gametophyte survival as well as holdfast fauna, and interfere with zoospore settlement. Given the microscopic size of the gametophyte, 5 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.

If inundation is long lasting then the understory epifauna/flora may be adversely affected, e.g. suspension or filter feeding fauna and/or algal species. This biotope occurs in high wave exposures and therefore deposited sediments are unlikely to remain for more than a few tidal cycles, except in the deepest of rock-pools. Therefore the effects of depositing 5cm of fine sediment in a discrete event are likely to be transient.

Comely & Ansell (1988) recorded large *Echinus esculentus* from kelp beds on the west coast of Scotland in which the substratum was seasonally covered with "high levels" of silt. This suggests that *Echinus esculentus* is unlikely to be killed by smothering, however, smaller specimens and juveniles may be less resistant. A layer of sediment may interfere with larval settlement. If retained within the host biotope for extended periods a layer of 5cm of the sediment may negatively affect successive recruitment events.

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 '**Note Sensitive'**.

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

Smothering by sediment e.g. 30 cm material during a discrete event, is unlikely to damage *Laminaria hyperborea* plants but is likely to affect gametophyte survival, holdfast communities, epiphytic community at the base of the stype, and interfere with zoospore settlement. 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 within 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.

If clearance of deposited sediment occurs rapidly then understory communities are expected to recover quickly. If inundation is long lasting then the understory epifauna/flora may be adversely affected, e.g. suspension or filter feeding fauna and/or algal species. While this biotope occurs in high to moderate energy habitats (due to water flow or wave action) deposition of 30cm of sediment represents a large volume of material that would likely remain for a number of tidal cycles and is expected to damage understory flora/fauna as well as juvenile *Laminaria hyperborea*.

Comely & Ansell (1988) recorded large *Echinus esculentus* from kelp beds on the west coast of Scotland in which the substratum was seasonally covered with "high levels" of silt. This suggests that *Echinus esculentus* is unlikely to be killed by smothering, however, smaller specimens and juveniles may be less resistant. A layer of sediment may interfere with larval settlement. If retained within the host biotope for extended periods a layer of 5cm of the sediment may negatively affect successive recruitment events.

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

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 regarding the genetic modification or effects of translocation of native kelp populations was found.

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 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 *U.pinnatifida* and re-dominate the substratum. However, Thompson & Schiel (2012) suggested the fucoid recovery was partially due to an annual *Undaria pinnatifida* die back, which as noted by Heiser *et al*., (2014) 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). While *Undaria pinnatifida* may replace *Laminaria hyperborea* in some locations within the UK, at the time of writing there is limited evidence available to assess what ecological impacts this invasion may have on *Laminaria hyperborea* associated communities e.g. red seaweeds.

Undaria pinnatifida was successfully eradicated on a sunken ship in Clatham Islands, New Zealand, by applying a heat treatment of 70 °C (see Wotton *et al*., 2004) however numerous other eradication attempts have failed, and as noted by Farrell & Fletcher (2006) 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 INIS is assessed as '**High**'.

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

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).

Echinus esculentus is susceptible to 'Bald-sea-urchin disease', which causes lesions, loss of spines, tube feet, pedicellariae, destruction of the upper layer of skeletal tissue and death. It is thought to be caused by the bacteria Vibrio anguillarum and *Aeromonas salmonicida*. Bald sea-urchin disease was recorded from *Echinus esculentus* on the Brittany Coast. Although associated with mass mortalities of *Strongylocentrotus franciscanus* in California and *Paracentrotus lividus* in the French Mediterranean it is not known if the disease induces mass mortality (Bower, 1996).

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	Medium Q: High A: High C: High	Medium Q: High A: High C: High

Christie *et al.* (1998) observed *Laminaria hyperborea* habitat regeneration following commercial *Laminaria hyperborea* trawling in south Norway. Within the study area trawling removed all large canopy-forming adult *Laminaria hyperborea*, however sub-canopy recruits were unaffected. Within 2-3 years of harvesting a new canopy had formed 1m off the seabed. The associated holdfast communities recovered in 6 years however the epiphytic stipe community did not fully recover within the same time period. Christie *et al*., (1998) suggested that kelp habitats were relatively resistant to direct disturbance of *Laminaria hyperborea* canopy.

Recurrent disturbance occurring at a smaller time scale than the recovery period of 2-6 years (stated above) could extend recovery time. 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* (Fletcher *et al*., 2006). 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.

Following disturbance or in areas were recurrent rapid disturbance occurs *Laminaria hyperborea* recruitment could also be affected by interspecifc competitive interactions with Invasive Non Indigenous Species or ephemeral algal species (Brodie *et al*., 2013; Smale *et al*., 2013), however evidence for this is limited and thus not included within this assessment. Removal of kelp canopies can also result in the decline of the associated epiphytic and understory red algal species (Hawkins & Harkin, 1985). Removal of *Echinus esculentus* from IR.MIR.KR.Lhyp.GzFt/Pk could also reduce grazing pressure and change the character of the biotope.

Sensitivity assessment. Resistance to the pressure is considered '**Low**', and resilience '**Medium**'. The sensitivity of this biotope to damage to seabed surface features is assessed as '**Medium'**.

Removal of non-target species	Low Q: High A: High C: High	Medium Q: High A: High C: High	Medium Q: High A: High C: High

Incidental/accidental removal of *Laminaria hyperborea* from extraction of other marine resources, e.g. fisheries or aggregates, is likely to cause similar effects to that of direct harvesting of *Laminaria hyperborea*; hence the same evidence has been used for both pressure assessments.

Christie *et al.* (1998) observed *Laminaria hyperborea* habitat regeneration following commercial *Laminaria hyperborea* trawling in south Norway. Within the study area trawling removed all large canopy-forming adult *Laminaria hyperborea*, however sub-canopy recruits were unaffected. Within 2-6years of harvesting a new canopy had formed 1m off the seabed. The associated holdfast communities recovered in 6 years however the epiphytic stipe community did not fully recover within the same time period. Christie *et al.*, (1998) suggested that kelp habitats were relatively resistant to direct disturbance of *Laminaria hyperborea* canopy.

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Sensitivity assessment. Resistance to the pressure is considered '**Low**', and resilience '**Medium**'. The sensitivity of this biotope to damage to seabed surface features is assessed as '**Medium'**.

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