Laminaria digitata on moderately exposed sublittoral fringe bedrock

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

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Kelp forest exposed at low tide with rocky shore in background.
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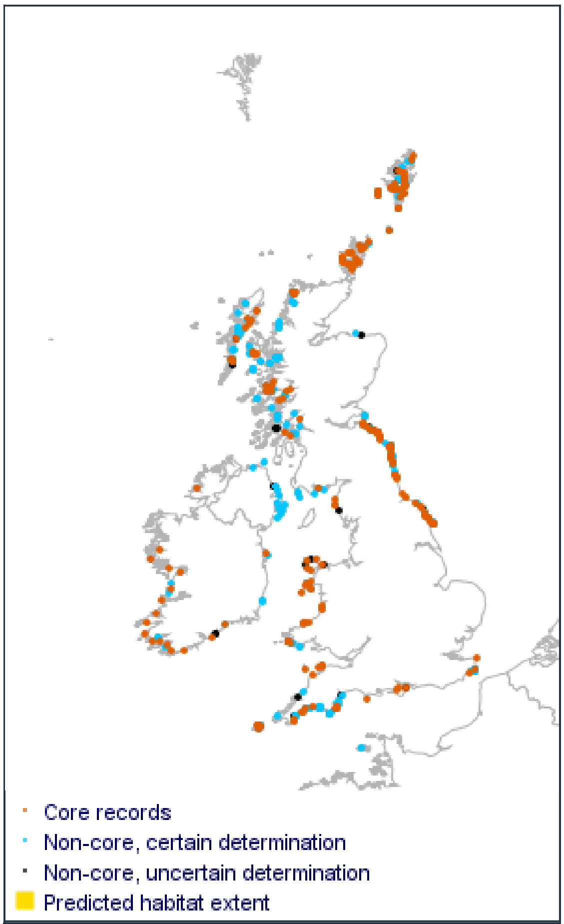

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Claire Jasper & Jacqueline Hill **Refereed by** This information is not refereed.

Summary

UK and Ireland classification

EUNIS 2008	A3.2111	*Laminaria digitata* on moderately exposed sublittoral fringe bedrock
JNCC 2015	IR.MIR.KR.Ldig.Ldig	*Laminaria digitata* on moderately exposed sublittoral fringe bedrock
JNCC 2004	IR.MIR.KR.Ldig.Ldig	*Laminaria digitata* on moderately exposed sublittoral fringe bedrock
1997 Biotope	IR.MIR.KR.Ldig.Ldig	*Laminaria digitata* on moderately exposed sublittoral fringe rock

Description

Exposed to sheltered sublittoral fringe bedrock dominated by a dense canopy of *Laminaria digitata*, often with a wide range of filamentous and foliose red seaweeds beneath. The most frequently occurring red seaweeds are *Palmaria palmata*, *Corallina officinalis*, *Mastocarpus stellatus*, *Chondrus crispus*, *Lomentaria articulata* and *Membranoptera alata*. Generally, the rocky substratum is covered by encrusting coralline algae, on which occasional limpets *Patella vulgata* and topshells *Gibbula cineraria* graze. A wide variety of fauna occurs, some of the most commonly occurring species being the sponge *Halichondria panicea* and the tube-building polychaete *Spirobranchus triqueter*. Kelp holdfasts provide a refuge for a varied assemblage of species such as sponges and the limpet *Patella pellucida*, while encrusting bryozoans such as *Electra pilosa* more often are found on the fronds of foliose red seaweeds. Solitary ascidians may be locally abundant where overhanging or vertical rock occurs, while the hydroid *Dynamena pumila* can be abundant on *Fucus serratus* and *Laminaria* sp. fronds. On exposed, wave-surged shores, the robust red seaweeds *Mastocarpus stellatus*, *Chondrus crispus* and *Corallina officinalis* can form a dense turf beneath the kelp along with the occasional green seaweed *Ulva lactuca*. Similarly, on such shores, the mussel *Mytilus edulis* can occur in extremely dense aggregations on the rock, beneath the kelp canopy. (Information from Connor *et al*., 2004; JNCC, 2015).

Depth range

Lower shore, 0-5 m

Additional information

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Listed By

- none -

Further information sources

Search on:

JNCC

Habitat review

Ecology

Ecological and functional relationships

Kelp habitats are dynamic ecosystems where competition for space, light and food result in patchy distribution patterns of flora and fauna. Kelp beds are diverse species rich habitats and over 1,200 species have been recorded in UK moderately exposed kelp biotopes (MIR.KR) (Birkett *et al*. 1998b). Kelps are major primary producers, up to 90% of kelp production enters the detrital food web and is probably a major contributor of organic carbon to surrounding communities (Birkett *et al*. 1998b). Major interactions are thought to be the effects of competition for space, shading, herbivory and predation.

- In most kelp biotopes there is evidence of strong competition for space, especially for space on a favourable substratum. Competition may occur between individual plants of the same species, between kelps and substratum-colonizing species of animals and other algae and between colonial animals and encrusting algae. Competition for space between individuals and species is dynamic, resulting in a constantly changing patchwork of species covering any suitable substrata within the biotope.
- The blades of *Laminaria digitata* plants form a canopy layer which may cut off much of the incident irradiance. This restricts the development of species with high light demands so that the understorey of plants becomes dominated by shade tolerant red algae. It also allows species normally restricted to the lower infralittoral in kelp-free areas to compete more effectively in the reduced light levels of the kelp bed and so are found at shallower depths.
- Within kelp beds there are relatively few species that are directly grazing either the kelp or the understorey algae as the enzymes required to directly utilise algae as food are not common. Those species able to graze directly on the kelp include the gastropods: *Gibbula* spp., *Littorina* spp., *Haliotis tuberculata* (in the Channel Islands only), *Patella pellucida*, *Lacuna* spp. and the Rissoidae, together with some amphipods and isopods. *Patella pellucida* grazes epiphytes and the kelp tissue directly, forming pits similar to the home scars of intertidal limpets. The larger, *laevis* form excavates large cavities in the holdfast of *Laminaria* spp. which creates tissue damage weakening the adult plant and possibly contributes to its loss due to wave action and storms (Kain, 1979). Infestation with *Patella pellucida* varies between sites and decreases with depth.
- The molluscs *Patella vulgata* and *Gibbula* spp. and chitons (especially in the north) graze the rock below leaving, with the effects of frond-sweeping, extensive bare crustose coralline algae on the rock.
- Predation within kelp beds has not been well studied in the UK. Although some species are known to prey on others, such as starfish on mussels, very little is known of the predator-prey relationships for the many species occurring in kelp beds.
- The abundance of filter feeding organisms such as sponges, bryozoans and tunicates which colonize both the rock and kelp plants indicates the importance of planktonic input to the benthic community of the biotope. Although very little information is available about planktonic communities in kelp beds it can be assumed that there will be larger inputs of larval stages from species with bentho-pelagic life cycles than in the general plankton (Birkett *et al*, 1998b).
- Kelp plants are also exploited as a habitat; the holdfast, stipe and frond each support a different type of community although only the oldest *Laminaria digitata* plants will have

epiphytic life on the stipe (which is smooth in all but the oldest individuals); however, holdfasts shelter a particularly rich diversity of animals from a wide range of taxa (see Habitat complexity).

Seasonal and longer term change

Most species in the biotope are perennial and seasonal changes are likely to be in condition of individuals rather than presence or absence.

- Growth rate of *Laminaria digitata* is seasonally controlled with a period of rapid growth from February to July and one of slower growth from August to January. Increased wave exposure and storms in winter months are likely to erode *Laminaria digitata* blades so that they appear tattered in winter months and overall standing biomass is reduced. Periodic storms are also likely to remove older and weaker plants creating patches cleared of kelp and increasing the local turbidity. Cleared patches may encourage growth of sporelings or gametophyte maturation. Growth of understorey algae is also reduced in the winter months.
- Some species of algae have seasonally heteromorphic life histories spending a part of the year as a cryptic or encrusting growth form and only becoming recognisable in the foliose phase of their life cycles. The occurrence of such algae is often seen as the occurrence of 'ephemeral algae'. Some hydrozoans may be present in the kelp bed in their attached, colonial form only for a part of the year, spending the rest of the year as medusae.

It should be emphasised that present understanding of the natural fluctuations in the species assemblages, populations, distribution and diversity of species in kelp beds is very limited.

Habitat structure and complexity

The structure of kelp beds is complex with many different habitats i.e. bedrock, crevices, sediment pockets, the holdfast, stipe and blade of the plants themselves.

- Holdfasts provide refuge to a wide variety of animals supporting a diverse fauna that represents a sample of the surrounding mobile fauna and crevice dwelling organisms, e.g. polychaetes, small crabs, gastropods, bivalves, and amphipods.
- Kelp fronds may be colonized by encrusting bryozoans and hydroids and are grazed by molluscs such as the blue-rayed limpet *Patella pellucida*.
- Older rougher stipes of *Laminaria digitata* provide a substratum for a large number of epiphytic flora and fauna and it has been estimated that rugose stipes provide one and a half times that surface area provided by the bedrock (Jones *et al*., 2000).
- The bedrock offers surfaces for settlement and shelter of species and is colonized by encrusting and foliose red algae with a variety of tubicolous animals and ascidian species attached.

Productivity

Kelp plants are the major primary producers in the marine coastal habitat. Within the euphotic zone kelps produce nearly 75% of the net carbon fixed and large kelps often produce annually well in excess of a kilogram of carbon per square metre of shore. However, only about 10% of this productivity is directly grazed. Kelps contribute 2-3 times their standing biomass each year as particulate detritus and dissolved organic matter that provides the energy supply for filter feeders and detritivores in and around the kelp bed. Dissolved organic carbon, algal fragments and microbial film organisms are continually removed by the sea. This may enter the food chain of local subtidal ecosystems, or be exported further offshore. Rocky shores make a contribution to the food of many marine species through the production of planktonic larvae and propagules which contribute to pelagic food chains.

Recruitment processes

Most species in this biotope produce planktonic propagules annually and so recruitment is often from distant sources and is frequent.

- Benthic species, plant and animal, that possess a planktonic stage: gamete, spore or larvae, are likely to be influenced by kelp mediated alteration of fluid and particulate, and consequently larval fluxes. Kelp canopies also affect the physical environment, such as the substratum, experienced by actively settling planktonic larvae. The substrata beneath kelp plants for example, are often dark and sediment laden, conditions likely to affect larval settlement and post settlement survival. Both the demographic structure of populations and the composition of assemblages may be profoundly affected by variation in recruitment rates driven by such factors.
- *Laminaria digitata* plants are fertile all year round with maximum production of spores in July - August and November - December. Young sporophytes (germlings) appear all year with maxima in spring and autumn. Chapman (1981) demonstrated that substantial recruitment of *Laminaria digitata* plants to areas barren of kelp plants was possible up to 600m away from reproductive plants.
- Among sessile organisms, patterns fixed at settlement, though potentially altered by post settlement mortality, obviously cannot be influenced by dispersal of juveniles or adults.
- Some of the species living in kelp beds do not have pelagic larvae, but instead have direct development producing their offspring as 'miniature adults'.

Time for community to reach maturity

Kain (1975) examined the recolonization of cleared concrete blocks by kelp plants and other algae and found that *Laminaria digitata* plants were re-established within 2 years and that red algae returned with a year. Many other characterizing species have planktonic larvae and/or are mobile and so can migrate into the affected area. Colonization of most species of fauna inhabiting kelp holdfast, for example, were found as early as one year after kelp trawling of *Laminaria hyperborea* plants in Norway, although numbers of both individuals and species, especially isopods and amphipods, increase with a corresponding increase in holdfast size (Christie *et al*, 1998). However, although these species colonize the biotope quite rapidly maturity of the overall community is likely to be longer. For example, encrusting coralline algae such as *Lithophyllum incrustans* are slow growing (2-7 mm per annum - see Irvine & Chamberlain 1994) and recruitment of other species to the kelp bed may take longer. In dredged kelp beds in Norway for example, although the rock between *Laminaria hyperborea* plants was uniformly covered with coralline algae after 3 years, the more diverse community of cnidarians, bryozoans and sponges associated with coralline algae seen on undredged plots was absent (Birkett *et al*., 1998b). Within five years, however, the biotope is likely to have reached maturity.

Additional information

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Preferences & Distribution

Habitat preferences

Depth Range	Lower shore, 0-5 m
Water clarity preferences	
Limiting Nutrients	Nitrogen (nitrates), Phosphorus (phosphates)
Salinity preferences	Full (30-40 psu)
Physiographic preferences	Enclosed coast / Embayment, Open coast, Strait / sound
Biological zone preferences	Sublittoral fringe
Substratum/habitat preferences	Bedrock, Large to very large boulders
Tidal strength preferences	Moderately Strong 1 to 3 knots (0.5-1.5 m/sec.), Very Weak (negligible), Weak < 1 knot (<0.5 m/sec.)
Wave exposure preferences	Exposed, Moderately exposed, Sheltered
Other preferences	

Additional Information

🐾 Species composition

Species found especially in this biotope

- *Umbonula littoralis*

Rare or scarce species associated with this biotope

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Additional information

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

IR.MIR.KT.Ldig.Ldig occurs on bedrock and boulders subject to moderate to very weak tidal streams in wave exposed to sheltered conditions. The community is characterized by a dense *Laminaria digitata* canopy, beneath which is a diverse understory community of varied red seaweed, ascidians and bryozoans. The kelp supports holdfast fauna and both kelp and red seaweeds support encrusting or erect bryozoans. The rock surface covered by encrusting corallines.

In undertaking this assessment of sensitivity, an account is taken of knowledge of the biology of all characterizing species in the biotope. For this sensitivity assessment, *Laminaria digitata* is the primary focus of research, as loss of the kelp canopy would represent a loss of the biotope. However, it is recognized that the red algal community also defines the biotope. Examples of important species groups are mentioned where appropriate.

Resilience and recovery rates of habitat

The available evidence indicates that the recovery of kelp biotopes, where kelp has been entirely removed, requires at least two years. Re-colonization of concrete blocks by *Laminaria digitata* was investigated by Kain (1975) at Port Erin, Isle of Man. *Laminaria digitata* was considered re-established two years after removal, with the characterizing red foliose algae following one year later. Similarly, recovery after simulated harvesting of a standing crop of *Laminaria digitata* occurred within 18-20 months (Kain, 1979). While colonization of young *Laminaria* sporophytes may occur one year after initial substratum clearance (Kain 1979), the return of the biotope to its original mature condition is likely to lag behind this recolonization. These findings agree with previous studies which showed that when 60% of sporophytes (adult alga) were removed from a location, 18 months were required for the stand to rejuvenate (Perez, 1971), while in France, CIAM (Le Comité Interprofessionel des Algues Marines) proposed that, regardless of collection method, the restoration of stands of laminarians took up to 18 months post harvesting (Arzel, 1998). Some disparities between reported recovery rates do exist, with cleared plots in Helgoland taking 25 months, probably because plots were burned to ensure total removal of spores and germlings (Markham & Munda, 1980). Even after 25 months, although macroalgal density had returned to pre-clearance levels, the *Laminaria digitata* were smaller than those on undisturbed plots, suggesting full recovery needs longer than 25 months (Markham and Munda, 1980).

The seasonal timing of macroalgal removal impacts recovery rates. Engelen *et al.* (2010) showed that removal of 0.25 m^2 areas of *Laminaria digitata* forest in the spring and autumn had different recovery rates, with autumn recovery more rapid than spring (taking a minimum of 12 months). Return to conditions prior to removal took 18-24 months, with competition for space by *Saccorhiza polyschides* impacting recovery rates in the first year of recolonization (Engelen *et al.*, 2010). The growth rate of *Laminaria digitata* changes with the seasons. Growth is rapid from February to July, slower in August to January, and occurs diffusely in the blade (Kain, 1979). This diffuse growth may enhance its resistance to potential grazers. Spores are produced at temperatures lower than 18°C with a minimum of 10 weeks a year between 5-18 °C needed to ensure spore formation (Bartsch, 2013). Thus temperature and season impacts the level of reproductive activity. In order to maximise survival rates of mature gametophytes, gametophyte development can be delayed by the algae until optimum conditions return and the gametophyte produces gametes (Van den Hoek *et al.*, 1995), which suggests a degree of resistance to short-term changes in temperature which may be anthropogenic in origin. However, seaweeds have been cited as being particularly sensitive to short-term warming events (Dayton & Tegner, 1984; Smale & Wernberg, 2013; Wernberg *et al.*, 2013; from Smale *et al.*, 2013).

Smith (1985) recorded the recovery of *Laminaria longicruris* and *Laminaria digitata* following total experimental clearance within Lobster Bay, Nova Scotia. Within three months *Laminaria longicruris* recovery was well established, and experimental clearance plots were indistinguishable from the surrounding habitat. *Laminaria digitata* however required two years to fully recover following clearance.

The dispersal of *Laminaria digitata* spores and subsequent successful recruitment has been recorded 600 m from reproductive individuals (Chapman, 1981). Local water movement plays an important role in the potential recovery of a biotope, with spores dependent on currents to extend their dispersal range, although the majority of larvae settle within its local habitat (Brennan *et al.*, 2014). If only part of the biotope is destroyed then recovery is likely to be fast. However, if the whole of a local biotope is destroyed, then its recovery depends on spores from an external source and, if the biotope is isolated from others of its kind, then recovery may be very slow. As kelp are attached to the substratum and have no mobility, recovery of the biotope where the kelp has been removed will depend on recolonization of cleared surfaces by germlings. The frequency of disturbance is also important when considering the resilience of this biotope to various pressures, especially in terms of allowing novel species to out-compete *Laminaria digitata* in local areas. A loss of genetic diversity is not regarded as an issue for this species unless additional pressures result in the isolation and fragmentation of wild coastal populations (Valero *et al.*, 2011). Genetic differentiation in wild populations occurs within 10 km with genetic flow occurring between adjacent species (Billot *et al.*, 2003). Opportunistic species such as *Sargassum muticum* and *Codium fragile* exploit gaps in the kelp bed and out-compete *Laminaria digitata*, so that high frequency, low impact disturbances may make the kelp stands more vulnerable to competition from these and other turf-forming algae; especially if climate change results in temperature shifts (Staehr *et al.*, 2000; Scheibling & Gagnon, 2006; Connell & Russell 2010).

Experimental work in Nova Scotia (Atlantic coast of Canada), where *Laminaria longicruris* (and its understorey of *Laminaria digitata*) is harvested has shown that if kelps beds are destroyed/partially destroyed, grazing sea urchins may prevent regeneration and recruitment of kelp populations. It is thought that kelp harvesting removes the cover and protection of urchin predators (lobsters, crabs, fish) and a reduction in predator pressure, due either to kelp harvesting or lobster fishing, enables increases in urchin populations which graze destructively on *Laminaria* spp., forming barrens (Bernstein *et al.* 1981). Grazers are responsible for less than 20% of kelp produced nutrients entering the food web; the majority enters as detritus or dissolved organic matter. Under healthy conditions, grazers do not feed on the kelp themselves, but on their epibiota, with a few rare examples such as the blue rayed limpet (Krumhansl & Scheibling, 2012). The urchin barrens recorded off the coast of Norway are not common to UK waters with deforestation by urchins instead restricted and patchy (although some have been noted in Scotland; Smale *et al.*, 2013). Stressed environments may be more susceptible to overgrazing by urchins, highlighting the need to consider these stressors as accumulative rather than isolated.

Resilience assessment. Evidence from Engelen *et al.* (2011) indicated that complete recovery of *Laminaria digitata* and its associated epibiota occurs 18-24 month after complete removal of *Laminaria digitata*. Smith (1985) also suggested 24 months for the recovery of a *Laminaria digitata* bed. Therefore, resilience has been assessed as ‘**High**’. Competition between *Laminaria digitata* and *Saccorhiza polyschides* can also increase recovery time. In addition, experimental evidence (Kain, 1975, 1979; Markham & Munda, 1980) suggest that if the entire community is removed (e.g. where resistance is 'None') that the recovery of the kelp bed and red algal community may take longer, possibly up to three years, so that resilience is assessed as '**Medium**'.

Hydrological Pressures

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

Laminaria digitata is distributed from Brittany to the coast of Norway, while its UK distribution encompasses the whole of the UK coast (Blight and Thompson, 2008). Its distribution suggests that the species would tolerate chronic temperature change (e.g. by 2°C for a year). However, local populations may have acclimatized to local physical conditions meaning that populations at the extremes of the species' range are less comparable than those populations in the middle of its range. Additionally, the distribution data of this species suggests it is a northern species, as such, it will be vulnerable to increases in temperature and may be out-competed at its southern limits by other kelp species.

The thermal optimum of *Laminaria digitata* is between 10-15°C, with reproductive ability impaired to 20% at 18°C (Arzel, 1998). Therefore while the current population may not be affected, recruitment may be reduced. Spore production only occurs between 5-10°C and is the most temperature sensitive stage of reproduction in *Laminaria digitata*. Outside this temperature range, reproduction is severely reduced and the species is at risk from local extinction in the long-term. In addition, a temperature increases to 22-23°C causes cell damage and death (Sundene, 1964; Bolton & Lüning, 1982). The sensitivity of this species, therefore, relies on the current sea temperatures of the specific location (Bartsch *et al.*, 2013). A minimum of 10 weeks a year between 5-18°C is needed in order to ensure spore formation and hence reproduction (Bartsch *et al.*, 2013).

Combining predicted sea surface temperate over the next century with the current distribution of *Laminaria digitata*, Merzouk & Johnson (2011) predict an expansion of its northern limits and localised extinctions across its southern range edge (Mid Bay of Biscay, Northern France and southern England; Birkett *et al.*, 1998). Suggesting at sites where sea temperature is artificially increased as a result of anthropogenic activity (e.g. effluent output) local extinction of the biotope may occur (Raybaud *et al.*, 2013) especially if combined with high UK summer sea temperatures in southern examples of this biotope (Bartsch *et al.*, 2013). In southern examples of IR.MIR.KT.LdigT, *Laminaria digitata* may also be out-competed by its Lusitanian competitor *Laminaria ochroleuca* which is regionally abundant across the south UK coastline (Smale *et al.*, 2014).

Sensitivity assessment. Species within the habitat are likely to vary in response to temperature change, despite this, *Laminaria digitata* is likely to withstand an increase in temperature at the benchmark level, and this biotope is therefore assessed as having a **'High'** resistance to this pressure. Resilience is, therefore, also **'High'**. If the temperature increase is short-term (a 5°C increase in temp for one month period) this biotope is considered **'Not sensitive'** at the benchmark level. However, because this pressure may affect the reproductive stage of the algae, over periods longer than one year, if the temperature does not facilitate spore production then a temperature increase of 5°C is likely to negatively affect the biotope and may result in its local loss at the extremes of its range, especially in the light of climate change which has seen the northward retreat of *Laminaria digitata* biotopes in Europe (Raybaud *et al.*, 2013).

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

The thermal optimum of *Laminaria digitata* is between 10-15°C, with reproductive ability impaired to 20% at 18°C (Arzel, 1998). Therefore while the current population may not be affected, recruitment may be reduced. Spore production only occurs between 5-10°C and is the most temperature sensitive stage of reproduction in *Laminaria digitata*. Outside this temperature range, reproduction is severely reduced and the species is at risk from local extinction in the short-term. In addition, a temperature increase to 22-23°C causes cell damage and death (Sundene, 1964; Bolton & Lüning, 1982). During an exceptionally warm summer in Norway, Sundene (1964) reported the destruction of *Laminaria digitata* plants exposed to temperatures of 22-23°C. The sensitivity of this species, therefore, relies on the current sea temperatures of the specific location (Bartsch *et al.*, 2013). A minimum of 10 weeks a year between 5-18°C is needed in order to ensure spore formation and hence reproduction (Bartsch *et al.*, 2013).

With a warming climate, Merzouk & Johnston (2011) predict an expansion of the northern limits of this species. The northward retreat of Laminaria digitata has been predicted using the IPCC climate change model, suggesting that in conditions of increased temperatures by anthropogenic means (e.g. effluent output) local extinction of the biotope may be likely (Raybaud *et al.*, 2013) especially if the increases in summer temperatures inhibiting reproduction recorded by Bartsch *et al.* (2013) continues.

Sensitivity assessment. The dominant kelp *Laminaria digitata* is thought to be a northern species and likely to retreat north as a result of climate change. Therefore, it is unlikely to be sensitive to a reduction in temperature at the benchmark level. Several members of the red algal community are found from the lower shore to the sublittoral, and probably not sensitive to changes at the benchmark level, as if some individual species may reduce in abundance or be lost, the diverse red algal community will remain. Therefore, a resistance of **'High'** is suggested, with a resilience of **'High'** and 'the biotope is regarded as **'Not sensitive'** at the benchmark level.

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

Kelps are tolerant to short-term daily fluctuation in salinity and are recorded as tolerating 5-60 psu; however, they are much less tolerant to long-term changes with growth and photosynthetic rates declining either side of 20-45 psu (Gordillo *et al.*, 2002, Karsten, 2007). Despite this tolerance, *Laminaria digitata* is considered to be a stenohaline species, and this biotope is only found in conditions of full salinity (Connor *et al.*, 2004). Therefore, other species probably out-compete *Laminaria digitata* at the limits of its salinity tolerance, meaning that despite the biotope's tolerance under conditions of no competition, under natural conditions this biotope is unlikely to occur in conditions above 40 psu.

Sensitivity assessment. This biotope is only recorded in conditions of full salinity and a change from full to hypersaline conditions (>40 psu) for a year is likely to result in major changes in the character of the biotope, including loss of the dominant kelp and members of the red algal community. Therefore, a resistance of '**Low**' is suggested, with a resilience of '**High**' and a resultant sensitivity of '**Low**'. However, in the absence of direct evidence, the overall confidence in the assessment is 'Low'.

Salinity decrease (local)	None Q: High A: High C: Medium	Medium Q: High A: High C: High	Medium Q: High A: High C: Medium

Birkett *et al.* (1998b) suggested that kelps are stenohaline, in that they do not tolerate wide fluctuations in salinity and require regular salinities of 30-35 psu to maintain optimum growth rates. Growth rate may be adversely affected if the kelp plant is subjected to periodic salinity stress. *Laminaria digitata* tolerates a large salinity range within a 24 hour period (5-60 psu; Karsten, 2007). At the extremes of this range; decreases in photosynthetic rates are evident, particularly at low salinities (Gordillo *et al.*, 2002). In the study by Karsten (2007), kelp thalli were kept at constant salinities for 5 days, with their photosynthetic rates measured after 2 and 5 days. The lower salinity limit for *Laminaria digitata* lies between 10 and 15 psu. On the Norwegian coast, Sundene (1964) found healthy *Laminaria digitata* plants growing between 15 and 25 psu. Axelsson & Axelsson (1987) indicated damage of the plants' plasma membranes occurs when salinity is below 20 or above 50 psu. Localized, long-term reductions in salinity, to below 20 psu, may result in the loss of kelp beds in affected areas (Birkett *et al.*, 1998b).

Red algae vary in their resistance to reduced or variable salinity, so that changes in salinity may change the species composition of the red algal community. In laboratory experiments, maximum rates of photosynthesis and respiration in *Palmaria palmata* were observed at a salinity 32 psu (Robbins, 1978) although photosynthetic rates were high down to a salinity of 21 psu. *Palmaria palmata* is likely to be tolerant of small changes in salinity because as an intertidal species it is regularly exposed to precipitation. *Corallina officinalis* inhabits rock pools and gullies from mid to low water. Therefore, it is likely to be exposed to short-term hyposaline (freshwater runoff and rainfall) and hypersaline (evaporation) events. However, its distribution in the Baltic is restricted to increasingly deep water as the surface salinity decreases, suggesting that it requires full salinity in the long-term (Kinne, 1971). Some of the fauna, including *Halichondria panicea*, are tolerant of a wide variety of salinity habitats from reduced to full salinity and are therefore unlikely to be affected by a drop in salinity at the benchmark level.

Sensitivity assessment. The main studies which this assessment is based on are laboratory studies. More weight is lent to studies carried out in the field as they provide more realistic estimates of how this species is likely to respond to pressures. Although *Laminaria digitata* cold survive reduced salinity conditions (i.e. 18-30) this biotope is only found in full salinity conditions (Connor *et al.*, 2004), this biotope is considered to have a resistance of '**None**' at the benchmark level as the biotope could be lost or replaced by variable salinity biotopes (e.g. IR.MIR.KR.Slat.Ldig) due to an increased abundance of *Saccharina latissima*. Resilience is considered '**Medium**' (2-10 years) due to the scale of the impact, giving a sensitivity of '**Medium**'.

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

This biotope occurs in a range of water flow conditions from moderately strong (0.5-1.5 meters /second) to very weak (negligible) (Connor *et al.*, 2004). Its flexible stipe and low profile holdfast allow it to flourish in areas with strong water currents. In Lough Ine in Ireland, *Laminaria digitata* forms dense forests in the fast flowing water of the Rapids where water speeds vary from 4-6 knots (ca 2-3 m/s) (Bassingdale *et al.*, 1948). *Laminaria digitata* is also found in very strong flows (>3.87 m/s) although it is often out-competed by *Alaria esculenta*. The biotope is not found in areas where sand scour occurs (associated with high water flow rates). The structure of the substratum typically of this biotope is also likely to reduce water flow by increasing frictional drag, providing some inherent resistance within the biotope. Therefore, the *Laminaria digitata* and its associated community will probably not be affected by a change of 0.1-0.2 m/s in peak mean spring bed flow velocity. *Laminaria digitata* partially achieves survival in a range of water flow conditions due to its blade morphology, which varies with flow, becoming narrower and more digitate as water flow rate increases (Sundene, 1964). In a laboratory study, this morphological adaptation was attributed to longitudinal stress with exposure to this stress over 6 weeks resulting in narrower blades and a significantly higher rate of cell elongation, compared to those plants that had not experienced the same stress. This study also suggested that plasticity would serve to decrease the risk of thallus damage in areas of greater exposure or in stormier conditions (Gerard, 1987).

Larval dispersal is in part governed by the local hydrodynamic regime; increased turbulence is associated with an increase in biotope connectivity and therefore a loss of larvae from the local system. A decrease in wave and current mediated water flow is identified by lower connectivity with other sites and a higher settlement rate within the local biotope (Robins *et al*., 2013). Therefore, an increase in water flow could result in larval loss from the local biotope, which if not balanced by a larval influx from another geographically different population, could result in the demise of the local biotope’s health; with a shift in the age structure of the population and a dearth of young alga. A decrease in the level of water flow is unlikely to have a detrimental effect because the species often grow in areas of low water movement where it may form extensive loose-lying populations (Burrows, 1958; cited in White and Marshall, 2007).

Sensitivity Assessment. ‘High’ resistance and by default a **‘High’** resilience to this pressure. Therefore, this biotope is regarded as **‘Not sensitive’** at the benchmark level’, although a prolonged increase in flow could result in loss of the biotope due to reduced local recruitment and competition from other species.

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

This biotope occurs in the shallow sublittoral and is therefore exposed to changes in emergence. Increased emergence will expose the biotope to air for longer periods leading to drying. *Laminaria digitata* is relatively resistant to desiccation, surviving up to 40% water loss (Dring & Brown, 1982). The desiccation tolerance of *Laminaria digitata* allows beds to extend a further 2 cm into the eulittoral zone where grazing pressure is removed (Southward & Southward, 1978). When exposed to the air, kelp canopies buffer the effects of high temperatures and water loss on organisms below their fronds with substratum temperatures on average 8-10°C lower under the canopy than bare rock, additionally decreasing water loss by >45% (Bertness *et al*, 1999).

An increase in the benchmark level for air exposure may result in the depression of the biotope’s upper limit; as this species‘ lower limit is set by competition with *Laminaria hyperborea* (Hawkins & Harkin, 1985). The upper, landward limits of *Laminaria digitat*a biotopes are generally set by competition with the brown algae *Fucus serratus* (Hawkins & Harkin, 1985); therefore, a decrease in the benchmark level for air exposure may result in the extension of the biotope’s upper limit. The main driver of competition between *Fucus serratus* and *Laminaria digitata* is based on the ability of *Fucus serratus* to control its respiration rates based on its desiccation rates, which *Laminaria digitata* is unable to do. Therefore, longer periods of emergence may result in a compression of *Laminaria digitata*’s extent as it is out-competed by *Fucus serratus* at its upper limit. The kelp is able to resist both an increase and decrease in emergence; however, this resistance is based on the free movement of this species within its environmental optima, shifting up or down the shore. Therefore, if an obstacle to movement perpendicular to the shoreline (e.g. sea defence) is then combined with a change in the emergence regime this biotope could undergo compression of its range and potentially local loss.

Sensitivity assessment. This pressure is a key driver of biotope extent because the upper and lower limits of this species are set by inter-species competition. In the direct footprint of the impact resistance is, therefore, probably **'Low'** (loss of 25-75%). Resilience is suggested as **'Medium'** (2-10 years) due to the scale of the impact. This biotope is therefore considered to have **'Medium'** sensitivity to the pressure.

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

The structure of kelps enables them to survive a range of wave conditions from wave exposed to sheltered conditions (Connor *et al*., 2004, Harder *et al*., 2006). Physiological differences between kelps are evident between low wave exposure and medium-high wave exposure. The greatest wet weight of *Laminaria digitata* occurs at low wave exposure (mean significant wave height <0.4 m) decreasing by a mean of 83% in medium to high wave exposures (mean significant wave height >0.4m; Gorman *et al*., 2013). At medium to high levels of wave exposure, *Laminaria digitata* biomass has been shown to decrease by 83% in the field (Wernberg & Thomsen, 2005). In areas of high wave exposure, *Laminaria digitata* may extend its upper limits into the lower eulittoral zone.

A flexible stipe and low profile holdfast allow *Laminaria digitata* to flourish in moderately to strongly wave exposed areas (as defined by MNCR, Connor *et al*., 2004). The absence of this biotope from extreme wave exposure and sheltered sites indicates a failure of the biotope to compete with other biotopes for space. The biotope IR.HIR.KFaR.Ala.Ldig typically replaces this biotope under conditions of extreme wave exposure, while in sheltered conditions, IR.LIR.K.Slat.Ldig becomes prevalent.

The physiology of seaweeds grown at exposed sites differs morphologically to those at sheltered sites with those exposed to greater wave action. A transplant experiment of *Laminaria digitata*, from exposed to sheltered sites resulted in a changed morphology with the frond widening, while individuals transplanted from sheltered to exposed sites became thinner and more streamlined (Sundene, 1964; Gerard, 1987). This morphological plasticity is evident during the spore stage; because of this, it is suggested that if wave height is increased or decreased the kelp will adapt morphologically over time to optimise its survival in the new environment.

The associated assemblage of the biotope also influences *Laminaria digitata*'s ability to withstand increases in wave action. The encrusting of the epiphytic *Membranipora membranacea* which reduces the ability of individual kelp to withstand wave action, increasing frond breakages and additionally reducing the maximum stress, toughness and extensibility of the kelp blade materials (Krumhansl *et al*., 2011).

Sensitivity assessment. The structure of *Laminaria digitata* makes it resistant to changes in wave action, although large sudden increases in wave action through events such as storms may result in the removal of individuals from the habitat. Also, an increase in wave exposure to very strong or higher, and a reduction in exposure to sheltered condition would result in a change in the community and biotope. However, a 3-5% change in significant wave height is unlikely to be significant and this biotope is, therefore, considered as having '**High**' resistance to changes in wave height at the benchmark level. Resilience is also considered as '**High**' at the benchmark, as there is no impact to recover from. Therefore, this biotope is '**Not sensitive**' at the benchmark level.

Chemical Pressures

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

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

	Resistance	Resilience	Sensitivity
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 digitata is less susceptible to coating than some other seaweeds because of its preference for exposed locations where wave action will rapidly dissipate oil. The effects of oil accumulation on the thalli are mitigated by the perennial growth of kelps. No significant effects of the *Amoco Cadiz* spill were observed for *Laminaria* populations and the *World Prodigy* spill of 922 tonnes of oil in Narragansett Bay had no discernible effects on *Laminaria digitata* (Peckol *et al.*, 1990). Mesocosm studies in Norwegian waters showed that chronic low-level oil pollution (25 µg/L) reduced growth rates in *Laminaria digitata* but only in the second and third years of growth (Bokn, 1985). Where exposed to direct contact with fresh hydrocarbons, encrusting calcareous algae have a high intolerance. The sensitivities of the faunal components of the kelp bed are not known although amphipods normally suffer high mortality in oil affected areas. Analysis of kelp holdfast fauna after the *Sea Empress* oil spill in Milford Haven illustrated decreases in the number of species, diversity and abundance at sites nearest the spill (SEEEC, 1998).

	Resistance	Resilience	Sensitivity
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.

Several of the species characteristic of the biotope are reported as having a high intolerance to synthetic chemicals. For instance, Cole *et al.* (1999) suggested that herbicides such as Simazine and Atrazine were very toxic to macrophytic algae. Hiscock & Hoare (1974) noted that almost all red algal species and many animal species were absent from Amlwch Bay in North Wales adjacent to an acidified halogenated effluent. Red algae have also been found to be sensitive to oil spill dispersants (O'Brien & Dixon 1976).

	Resistance	Resilience	Sensitivity
Radionuclide contamination	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence

Introduction of other substances	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed**.

De-oxygenation	High Q: High A: Medium C: High	High Q: High A: Medium C: High	Not sensitive 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). 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 but small invertebrate epifauna may be lost, causing a reduction in species richness. However, in wave exposed conditions, and hence high mixing, the effects of deoxygenation are likely to be short-lived. Therefore, resistance is assessed as **'High'**. Hence resilience is likely to be **'High'**, and the biotope is considered **'Not sensitive'** at the pressure benchmark.

Nutrient enrichment	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

High ambient levels of phosphate and nitrogen enhance spore formation in a number of *Laminaria* species (Nimura *et al*., 2002), but will eventually inhibit spore production, particularly at the limits of temperature tolerances as seen in *Saccharina latissima* (studied as *Laminaria saccharina*; Yarish *et al*., 1990). *Laminaria digitata* seems to follow this trend with a growth peak occurring in conjunction with nutrient upwelling from deeper waters in Norway (Gévaert *et al*., 2001). Macroalgal growth is generally nitrogen-limited in the summer, as illustrated by the growth rates of *Laminaria digitata* between an oligotrophic and a eutrophic site in Arbroath, Scotland (Davison *et al*., 1984). *Laminaria digitata* does not accumulate the significant internal nutrient reserves seen in some other kelp. Higher growth rates have been associated with alga situated close to sewage outfalls. However, after removal of sewage pollution in the Firth of Forth, *Laminaria digitata* became abundant on rocky shores from which they had previously been absent (Read *et al*., 1983). Enhancement of coastal nutrients is likely to favour those species with more rapid growth rates including turf-forming algae (Gorgula & Connell, 2004) which could explain *Laminaria digitata* absence from the Firth of Forth. In addition, epiphytic abundance and biomass on *Laminaria longicruris* increase under a eutrophic regime decreasing the ability of individual alga to photosynthesis and withstand pressure from water movement (Scheibling *et al*., 1999).

Sensitivity Assessment. The benchmark of this pressure (compliance with WFD 'good' status) allows for a slightly less diverse community of red, green and brown seaweeds with the greatest reduction in red species and an increase in the proportion of short-lived species under the WFD criteria for good status. However, this biotope is considered to be '**Not sensitive**' at the pressure benchmark, that assumes compliance with good status as defined by the WFD.

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

Organic deposition may result in siltation (see smothering and siltation change pressure) and subsequent re-suspension of organic particles reducing water clarity (see 'change in suspended solids' pressure). The deposition of sewage effluent into coastal environments resulted in the absence of *Laminaria digitata* and many other species from the coastline of the Firth of Forth (Read *et al*., 1983). The use of some kelp species in conjunction with fish aquaculture (to buffer the effects of organic enrichment in the local area) suggests that many commercial kelps (including *Laminaria digitata*) are tolerant to local increases in organic enrichment, although the level of enrichment experienced will be dependent on fish species and aquaculture design (Troell *et al*., 2003). In California, investigations into the effects of sewage effluent into coastal waters concluded that kelp was negatively affected by the organic enrichment of the surrounding waters (North & Schaefer, 1964). The addition of organic matter may also decrease water clarity and increase particulate matter in the water column the effects of these changes are assessed through the pressure ‘Changes in suspended solids’.

Johnston & Roberts (2009) conducted a meta-analysis, which reviewed 216 papers to assess how a variety of contaminants (including sewage and nutrient loading) affected 6 marine habitats (including subtidal reefs). A 30-50% reduction in species diversity and richness were identified from all habitats exposed to the contaminant types. Johnston & Roberts (2009) however also highlighted that macroalgal communities are relatively tolerant to contamination, but that contaminated communities can have low diversity assemblages which are dominated by opportunistic and fast growing species (Johnston & Roberts, 2009 and references therein).

Sensitivity Assessment. Therefore, the biotope is probably resistant of the direct effects of organic enrichment but may be sensitive to the effects of increased turbidity (see water clarity above) and eutrophication. Therefore, a resistance of **'Medium'** is suggested to represent a reduction in species richness and an increase in ephemeral green algae. Resilience is probably **‘High'** and the biotope is, therefore, considered to have a **'Low'** sensitivity at the pressure benchmark.

Physical Pressures

	Resistance	Resilience	Sensitivity
Physical loss (to land or freshwater habitat)	None Q: NR A: NR C: NR	Very Low Q: NR A: NR C: NR	High Q: NR A: NR C: NR

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: Low A: NR C: NR	Very Low Q: High A: High C: High	High Q: Low A: Low C: Low

A change in substratum type from bedrock to sedimentary is likely to have a similar effect as a ‘physical loss (to land or freshwater habitat) because kelp requires a stable, hard, substratum on which to settle. No evidence of this biotope occurring on sedimentary substratum was found in the literature. Also, it is scarce on the south-east coast of Ireland, in particular, Counties Wicklow and Wexford, due to lack of hard substratum.

Sensitivity assessment. This biotope is considered to have a resistance of **'None'** to this pressure as sedimentary habitats are unsuitable for *Laminaria digitata* and the associated attached biological assemblage. It would be unable to recover from this permanent change of habitat so resilience is **‘Very low'** and its sensitivity within the direct spatial footprint of this pressure is, therefore **‘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' to bedrock biotopes

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

The species characterizing this biotope are epifauna or epiflora occurring on rock and would be sensitive to the removal of the habitat. However, extraction of 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	Low Q: High A: Medium C: High	High Q: High A: Medium C: High	Low Q: High A: Medium C: High

Low-level disturbance (e.g. solitary anchors) are suggested as being unlikely to cause harm to the biotope as a whole due to their small impact footprint. In a review of the effects of trampling on intertidal habitats, Tyler-Walters & Arnold (2008) found no information on the effects of trampling on *Laminaria* species (*Laminaria digitata* or *Saccharina latissima*). The authors reported that laminarians are robust species but that trampling on blades at low tide could potentially damage the blade or growing meristem.

Traditionally *Laminaria digitata* was used on agricultural lands as fertilizers; now *Laminaria* spp. are used in a range of different products, with its alginates used in the cosmetic, pharmaceutical and agri-food industries (Kervarec *et al.*,1999; McHugh, 2003). Collection of *Laminaria digitata* by mechanical harvesting (trawling) is not done in the UK, (Netalgae, 2012). Trawling, used to harvest *Laminaria hyperborea* in Norway results in whole alga being removed from the substratum, and substantial scouring of the substratum, indicating that the use of trawls in a *Laminaria digitata* biotope is likely to detrimentally affect the biotope, regardless of the target species. In France, *Laminaria digitata* is harvested with a ‘Scoubidou’, a curved iron hook which is mechanically operated. This device is considered to be selective; only harvesting individuals older than 2 years (Arzel, 2002). France reportedly harvests 75,000t kelp, mainly consisting of *Laminaria digitata* annually (FAO, 2007). Davoult *et al.* (2011) suggested that the maintenance of a sustainable crop of *Laminaria digitata* was possible if the industry continues employing small vessels evenly dispersed along the coastline. This could protect against habitat fragmentation and buffer over exploitation (Davoult *et al.*, 2011). A fallow period of 18-24 months has been suggested for *Laminaria digitata* in France, where competition between the juvenile sporophytes of *Laminaria digitata* and *Saccorhiza polyschides* was indicated as a threat to the continued harvesting effort of *Laminaria digitata* (Engelen *et al.*, 2011).

Canopy removal of *Laminaria digitata* has been shown to reduce shading, resulting in the bleaching of sub-canopy algae (Hawkins & Harkins, 1985). Harvesting may also result in habitat fragmentation, a major threat to this biotope's ecosystem functioning (Valero *et al.*, 2011).

Harvesting and fishing trawls scour and abrade the seabed, dislodging macroalgae and their associated assemblages from the substratum. The impact footprint and recovery period to artificial abrasion by bottom trawling are dependent on the trawl's characteristics including; duration, type and size. There is little evidence in the literature concerning natural or low-level bedrock abrasion.

Sensitivity Assessment. Abrasion of the substratum could remove a proportion of the kelp and associated red algal community. Therefore, the biotope is considered to have **'Low'** resistance in the footprint of the pressure (loss of 25-75%) while resilience is **'High'** (within 2 years). Hence, the biotope is assessed as **'Low'** sensitivity.

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

The species characterizing this biotope group are epifauna or epiflora occurring on hard rock, which is resistant to subsurface penetration. Therefore, 'penetration' is '**Not relevant**'. The assessment for abrasion at the surface only is, therefore, considered to equally represent sensitivity to this pressure'. Please refer to 'abrasion' above.

Changes in suspended solids (water clarity)	Medium Q: High A: High C: High	High Q: High A: High C: High	Low 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). Light availability and water turbidity are principal factors in determining depth range at which kelp can be found (Birkett *et al.*, 1998b). Light penetration influences the maximum depth at which kelp species can grow and it has been reported that laminarians grow at depths at which the light levels are reduced to 1 percent of incident light at the surface. Maximal depth distribution of laminarians therefore varies from 100 m in the Mediterranean to only 6-7 m in the silt laden German Bight. In Atlantic European waters, the depth limit is typically 35 m. In very turbid waters the depth at which kelp is found may be reduced, or in some cases excluded completely (e.g. Severn Estuary), because of the alteration in light attenuation by suspended sediment (Lüning, 1990; Birkett *et al.* 1998b). *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 digitata*, decrease kelp abundance and density.

An increase in SPM results in a increase in subsurface light attenuation. The absence of *Laminaria digitata* in the Firth of Forth was suggested to be caused by the outflow from a sewage treatment plant that increased the turbidity of the water and thus decreased photosynthetic activity, although the effect of turbidity was probably coupled with increased nutrient levels (Read *et al.*, 1983). Blue light is crucial for the gametophytic stages of *Laminaria digitata*, and several other congenic species (Lüning, 1980). Dissolved organic materials (yellow substance or gelbstoff) absorbs blue light (Kirk, 1976), therefore changes in riverine input or other land based runoff are likely to influence kelp density and distribution. In the silt-laden waters around Helgoland, Germany the depth limit for *Laminaria digitata* growth may be reduced to between 0 m and 1.5 m (Birkett *et al.* 1998b). In locations where water clarity is severely decreased, *Laminaria* species experience a significant decrease in growth from the shading of suspended matter and/or phytoplankton (Lyngby & Mortensen 1996, Spilmont *et al.*, 2009).

Sensitivity Assessment. A decrease in turbidity is likely to support enhanced growth (and possible habitat expansion) and is therefore not considered in this assessment. However, an increase in turbidity, is likely to result in loss of the deeper extent of the biotope. Therefore, resistance to this pressure is defined as '**Medium**' and resilience to this pressure is defined as '**High**'. Hence, sensitivity is assessed as '**Low**'.

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

No direct evidence of the effects of this pressure was found for this biotope although some studies were found for the sensitivity of *Saccharina latissima* to this pressure. An experiment by Roleda & Dethleff (2008) illustrated potential benefits to low levels of siltation including UV protection for *Saccharina latissima* for short periods. When burial under a variety of sediment types was extended beyond 7 days, symptoms of bleaching, tissue loss and diminished PSII function were exhibited (Roleda and Dethleff, 2011). A layer of fine grained sediment (0.1-0.2 cm thick) caused rotting of *Saccharina latissima* and 25% mortality after 4 weeks of coverage in a laboratory experiment. *Saccharina latissima* is considered to be more silt tolerant than *Laminaria digitata*, therefore suggesting that in locations of low wave and current mediated water flow; sedimentation is a threat to this biotope (Lyngby & Mortensen 1996). However, this study was carried out on disk samples from the thalli placed in petri dishes with no current flow. It is unlikely that this biotope would be found in such conditions of low flow, therefore the relevance of this study is questionable, additionally it is unclear how a whole plant would respond to siltation, however, the findings are still worth considering.

Sedimentation has additional negative effects on the zoospores of brown algae, with spores attaching to the only substratum available. Hence, fine sediment could interfere with recruitment, by preventing and deterring spores attachment to a hard substratum; resulting in their subsequent loss due to waves and currents (Devinny & Volse, 1978, Norton, 1978; Bartsch *et al.*, 2008). Field observations reveal that kelp is associated with accelerating sediment deposition and additionally prevent sediments being washed away because of their influence on local water current by increasing drag and thus particulate fall out (Airoldi, 2003 references therein). However, this sediment is associated with the holdfasts of the kelp and not the fronds. At higher levels of wave exposure, whiplash by kelp is common, and this, in turn, reduces sediment accumulation at these sites (Kennelly 1989; Melville and Connell, 2001; cited in Airoldi, 2003).

Sensitivity Assessment. The resistance of this biotope to this pressure is assessed as **'High'** because despite the dramatic effect of siltation on *Laminaria digitata* under conditions of no water motion (Lyngby & Mortensen 1996), this biotope exists in water regimes which should favour the rapid exportation of sediment from the biotope, giving it an inherent level of protection against this pressure. Resilience to this pressure is regarded as **‘High’.** This biotope is regarded as **‘Not sensitive’** to this pressure at the benchmark.

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

The evidence suggests that *Laminaria digitata* is sensitive to prolonged smothering (Roleda & Dethleff, 2011) (see ‘light‘ deposition above). While 5 cm of sediment coverage may be transported from the biotope relatively quickly a deposition of 30 cm is likely to remain in place for a longer period of time, especially in wave sheltered examples of the biotope. Therefore, heavy siltation' may have a greater effect on the health of the biotope, resulting in smothering of the epifauna and flora, the red algae community and holdfast fauna in particular. Therefore, the biotope is likely to have a **'Medium’** resistance to this pressure. Resilience to this pressure is regarded as **‘High’** and sensitivity to this pressure is therefore assessed as **‘Low’.**

Litter	Not Assessed (NA) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

Not assessed. It is feasible that discarded fishing line or plastic netting, or similar discards could tangle on kelp fronds and potentially damage or remove individuals. However, there was no evidence on which to base an assessment.

Electromagnetic changes	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence

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

It is feasible that localised light sources (e.g. post or harbour side lighting) might increase the length of time available for photosynthesis in a shallow example of the biotope, where overnight lighting and the biotope abut. However, no evidence was found to qualify any effect and sensitivity is not assessed.

Shading of shallow examples of the biotope (e.g. by the construction of pontoons or jetties) would limit the availability of light and have similar effects to that of increased turbidity (see above) in the affected area. The dominant kelp is likely to be excluded while shade-tolerant red algae may increase in abundance or be reduced to encrusting corallines and become dominated by faunal turfs, depending on the degree of shading. The biotope may be lost in the affected area, hence a resistance of **'Low'** is suggested, with a resilience of **'High'** and sensitivity of **'Low'**.

Barrier to species movement	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

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

Death or injury by collision	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

'Not relevant' to seabed habitats. NB. Collision by grounding vessels is addressed under 'surface abrasion'

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

Not relevant

Biological Pressures

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

No evidence regarding the genetic modification of this species was found. Harvesting is carried out on wild kelp stands in a sustainable 5 year cycle (Vea and Ask, 2011), therefore, translocation of this species is unlikely. In addition, if translocation of populations does occur, a loss in genetic diversity is not regarded as an issue for this species, unless additional pressures result in the isolation and fragmentation of wild coastal populations (Valero *et al*., 2011). Genetic differentiation in wild populations occurs within 10 km with genetic flow occurring between adjacent species (Billot *et al*., 2003). No evidence was found to suggest that *Laminaria digitata* hybridizes with other species.

Introduction or spread of invasive non-indigenous species	Low Q: High A: High C: High	Very Low Q: High A: Medium C: High	High Q: High A: Medium C: High

Competition with invasive macroalgae posing a potential threat to this biota, include *Undaria pinnatifida* and *Sargassum muticum* (Rueness, 1989). *Sargassum muticum* has been shown to competitively replace *Laminaria* species in Denmark (Staehr *et al*., 2000). In Nova Scotia *Codium fragile* competes successfully with native kelps for space including *Laminaria digitata*, by exploiting gaps within the kelp beds, once established the algal mat created by this species prevents recolonization by other macroalgae (Scheibling *et al*., 2008). Despite this, the associated assemblages of the respective macroalgae do not differ significantly (Schmidt & Scheibling, 2006)

Undaria pinnatifida has received a large amount of research attention as a major Invasive Non-

Indigenous Invasive 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.*, 1998b). Farrell & Fletcher (2006) suggested that native short-lived species that occupy similar ecological niches to *Undaria pinnatifida* 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 *Laminaria* sp. (Farrel & Fletcher, 2006; Hieser *et al.*, 2014).

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

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

Introduction of microbial pathogens	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Symptoms of disease are regularly seen on *Laminaria* species, however little evidence in the literature is apparent. Infection of *Laminaria japonica* sporophytes by *Pseudoalteromonas*, *Vibrio* and *Halomonas* result in the characteristic symptoms of hole-rotten disease (Wang *et al.*, 2008). Additionally, red spot disease may be caused by bacteria of the genus *Alteromonas* (Sawabe *et al.*, 1998). Hyperplasia or gall growths are often seen as dark spots on *Laminaria digitata* and have been associated with endophytic brown filamentous algae. It can be inferred from these observations that microbial pathogens may impact growth rates of individuals. There is no evidence in the literature that infection by microbial pathogens results in the mass death of *Laminaria* populations and the kelp themselves are known to regulate bacterial infections through iodine metabolism (Cosse *et al.*, 2009). Based on the lack of reported mortalities of the characterizing and associated species, the resistance is assessed as **'High'** resistance to this pressure. Hence, resilience is assessed as '**High'** and the biotope is assessed as **'Not sensitive'**.

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

Traditionally *Laminaria digitata* was added to agricultural lands as fertilizers; now *Laminaria* species are used in a range of different products, with its alginates used in the cosmetic, pharmaceutical and agri-food industries (Kervarec *et al.*, 1999; McHugh, 2003). In France, *Laminaria digitata* is harvested with a 'Scoubidou' (a curved iron hook which is mechanically operated). This device is considered to be selective; only harvesting individuals older than 2 years (Arzel, 2002). France reportedly harvests 75,000t kelp, mainly consisting of *Laminaria digitata* annually (FAO, 2007). If

Laminaria digitata, the key characterizing and structuring species of this biotope is removed then the biotope is considered lost and a significant alteration to the biotope classification and character of the habitat is likely.

Debate exists on whether kelp harvesting is detrimental to fish stocks. While some state that no negative consequences of harvesting have been documented (Vea & Ask, 2011); others suggest that as important foraging and nursery grounds for birds and fish, removal will inevitably result in negative consequences (Lorentsen *et al*., 2010). Canopy removal of *Laminaria digitata* has been shown to reduce shading, resulting in the bleaching of sub-canopy algae (Hawkins & Harkin, 1985). Harvesting may also result in habitat fragmentation, a major threat to this biotope's ecosystem functioning (Valero *et al*., 2011). In the UK harvesting of *Laminaria digitata* is currently restricted to manual removal and farming on small scales, it is therefore not surprising that no evidence of how wild UK kelp populations would react to commercial harvesting was found in the literature (Netalgae, 2012).

Sensitivity Assessment. This biotope has a resistance of **'None'** to this pressure in the footprint of the pressure, as the removal of its key characterizing and structural species, *Laminaria digitata* would result in the loss of the biotope. However, resilience is assessed as **'Medium'**, giving a sensitivity of '**Medium'** to this pressure.

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

Removal of *Laminaria digitata* as by-catch would result in the loss of the biotope. In healthy macroalgae communities, many species contribute to the balanced condition of the ecosystem. Disrupting this balance may cause top-down consequences for the biotope; for example, overfishing of top predators in Norwegian waters is thought to have caused the urchin bloom, subsequent overgrazing and proliferation of urchin barrens (Steneck *et al*., 2004).

Sensitivity assessment. Because of the nature of the pressure, resistance to it is considered as '**None'**, because it potentially involves the removal of *Laminaria digitata* from the biotope, which would result in its loss. Resilience to this pressure is assessed as **'Medium'**. The sensitivity of this biotope to the removal of the non-targeted catch is assessed as **'Medium'.**

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