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Laminaria digitata, ascidians and bryozoans on tide-swept sublittoral fringe rock

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

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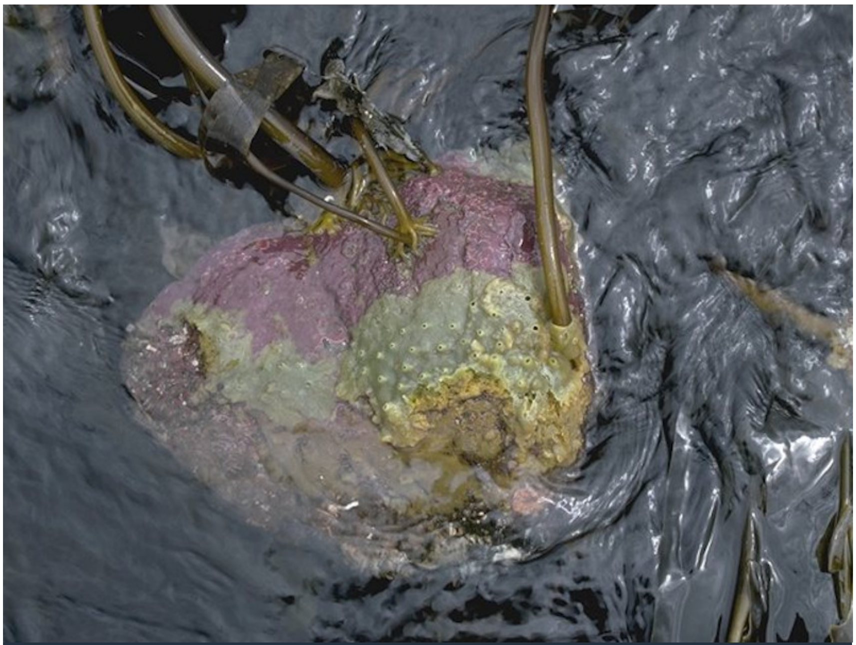

***Laminaria digitata*, ascidians and bryozoans on tide-swept sublittoral fringe rock**
Photographer: Ian Fuller
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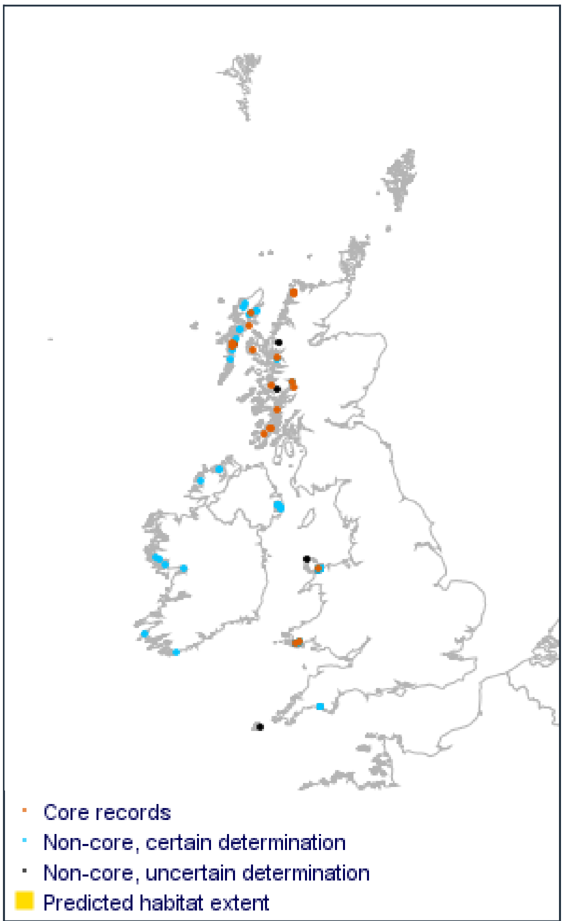

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Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Thomas Stamp & Charlotte Marshall **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A3.221	*Laminaria digitata*, ascidians and bryozoans on tide-swept sublittoral fringe rock
JNCC 2015	IR.MIR.KT.LdigT	*Laminaria digitata*, ascidians and bryozoans on tide-swept sublittoral fringe rock
JNCC 2004	IR.MIR.KT.LdigT	*Laminaria digitata*, ascidians and bryozoans on tide-swept sublittoral fringe rock
1997 Biotope	IR.MIR.KR.Ldig.T	*Laminaria digitata*, ascidians and bryozoans on tide-swept sublittoral fringe rock

Description

Very sheltered bedrock, boulders and cobbles that are subject to moderate to strong tidal water movement characterized by dense *Laminaria digitata*, ascidians and bryozoans. Species richness is generally greater than in the non tide-swept *Laminaria digitata* biotope (MIR.Ldig.Ldig), with a greater abundance and wider range of foliose red seaweeds. The increased water movement encourages several filter-feeding faunal groups to occur. The sponges *Leucosolenia* spp., *Halichondria panicea* and *Hymeniacidon perleve* frequently occur on steep and overhanging faces. In addition, the ascidians *Ascidia conchilega*, *Dendrodoa grossularia* and colonial ascidians are also found. Areas where increased tidal movement influences such a community are in the narrows and/or intertidal sills of sealochs. This biotope may be found immediately below the tide-swept *Fucus serratus* biotope (SLR.Fserr.T). The sublittoral fringe of similarly sheltered shores that are not tide-swept are generally characterized by mixed *Saccharina latissima* and *Laminaria digitata* (SIR.Slat.Ldig) or *Saccharina latissima* (SIR.Slat). (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

Depth range

-

Additional information

-

Listed By

- none -

Further information sources

Search on:

G G G 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, including the surface of the kelp plants themselves. This is especially true of the components of tide-swept biotopes such as MIR.Ldig.T. Tide swept biotopes offer luxuriant conditions for suspension feeders by providing a continual supply of food and removing finer sediment that may otherwise interfere with their delicate feeding apparatus. As a result, strong competition between the suspension feeders that thrive in this biotope will mean that any available substratum is likely to be colonized. Much of the rock surface will be covered by a 'foundation' of encrusting calcareous algae on top of which other species will grow.
- 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 including Corallinaceae, *Palmaria palmata*, *Chondrus crispus* and *Ceramium nodulosum*. 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 graze either the kelp or the understorey algae directly, as the enzymes required to directly utilize algae as food are not common. However, the gastropod *Steromphala cineraria* is frequently found in this biotope and may graze the kelp, foliose red seaweeds and the rock below. The blue-rayed limpet *Patella pellucida* also grazes on kelp and, when younger, red seaweeds such as *Mastocarpus stellatus*, which is commonly found in the understory of this biotope. The edible sea urchin *Echinus* and green sea urchin *Psammechinus milaris* also graze on kelp species in addition to prey species such as bryozoans, tunicates and hydroids.
- Predation within kelp beds has not been well studied in the United Kingdom and very little is known of the predator-prey relationships for the many species occurring in kelp beds. The common shore crab *Carcinus maenas* is probably the largest mobile predator associated with this biotope and preys upon *Gibbula cineraria*.
- As mentioned previously, tide swept biotopes offer a continual supply of suspended particulate matter that support a thriving suspension feeding community. Suspension feeders in MIR.Ldig.T represent several different phyla.
    - **Sponges** Of the sponges, the breadcrumb sponge *Halichondria panicea* is most commonly associated with this biotope. This species is usually found as an

encrusting mat on rock and algae. *Hymeniacidon perleve* is also likely to be present.
  - **Ascidians** Both solitary and colonial ascidians are found in this biotope. The colonial ascidians *Botryllus schlosseri* (the star ascidian) and *Botrylloides leachi*, and the solitary baked bean sea squirt *Dendrodoa grossularia* are all frequent.
  - **Cnidaria** Several hydroid species are commonly found on rock below the kelp in this biotope, especially *Dynamena pumila* and *Sertularia argentea*.
  - **Crustacea** Crustacean suspension feeders associated with this biotope are not the most important group, in terms of frequency and abundance, but include the barnacles *Balanus crenatus* and *Semibalanus balanoides*.
  - **Annelida** The tube worm *Spirobranchus triqueter* is the most common suspension feeing annelid associated within this biotope. It was found in two thirds of the records of this biotope and can rapidly colonize patches of bare rock. Spirorbid worms may be found.
  - **Bryozoa** *Alcyonidium gelatinosum*, *Alcyonidium hirsutum*, *Electra pilosa*, *Membranipora membranacea* and *Scrupocellaria* spp. are all likely to compete for space on the fronds and stipes of the kelp plants.

  The dominance of suspension feeding fauna 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 flora and fauna 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). Epiphytes on the stipe may include the sponge *Halichondria panicea* and red algae *Palmaria palmata* and *Phycodrys rubens* whereas the frond is more likely to be colonized by the bryozoan *Membranipora membranacea*.

Seasonal and longer term change

Present understanding of the natural fluctuations in the species assemblages, populations, distribution and diversity of species in kelp beds is limited. The plants in this biotope are likely to experience some seasonal change in abundance, the general pattern being a lower percentage cover over the winter months. However, this biotope is limited to extremely sheltered habitats and therefore, the occurrence of winter storms is unlikely to affect it to the same extent that more wave exposed habitats would be affected.

- 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 experienced during winter months may erode *Laminaria digitata* blades and reduce the overall standing biomass. Periodic storms may remove older and weaker plants creating patches cleared of kelp. Cleared patches may encourage growth of sporelings or gametophyte maturation. Growth of understorey algae may also be reduced in the winter months.
- Concomitant with the reduction in available surface area of *Laminaria digitata* blades, a proportion of epiphytic bryozoans, ascidians and sponges will also be lost. However, epilithic representatives of these species will remain on the bedrock and boulders.
- Increased wave exposure and storm frequency over the winter months may also increase

the frequency of impacts from wave driven debris, such as pebbles and boulders. These impacts may create 'bare' patches on the surface of the bedrock, and the boulders themselves, which may be colonized by fast growing species including the tube worm *Spirobranchus triqueter*.

Habitat structure and complexity

Owing to the tide-swept habitat with which this biotope is associated, a diverse marine life is supported. The fast currents provide a continual supply of suspended material sustaining a profusion of both active and passive suspension feeders that dominate the fauna. Fine sediment is removed by the current and the settlement of material, that could otherwise be detrimental to the suspension feeders, is prevented. It is the complex structure of this habitat and its many different niches that allow such a diverse range of suspension feeders to coexist. Almost every possible substratum including the bedrock, boulders and cobbles, and the holdfast, stipe and blade of the *Laminaria digitata* itself, is covered with various flora and fauna. In addition to the luxuriant conditions for suspension feeders, Hiscock (1983) lists some the benefits of strong water movement to include the potential for a greater photosynthetic efficiency, thereby possibly increasing the depth penetration of the algae. Increased water movement has been associated with an increase in photosynthesis in several algal species including *Fucus serratus* and *Ascophyllum nodosum* (Robbins, 1968, cited in Hiscock, 1983).

- Holdfasts provide refuge to a wide variety of animals supporting a diverse fauna that may include polychaetes, small crabs, gastropods, bivalves, and amphipods.
- Kelp fronds are likely to be colonized by encrusting bryozoans (e.g. *Membranipora membranacea*), ascidians (e.g. *Botryllus schlosseri*), hydroids (e.g. *Dynamena pumila*) and sponges (e.g. *Halichondria panicea*).
- Stipes of *Laminaria digitata* can support a considerable epiphytic flora, mainly of smaller species (Gayral & Cosson, 1973; Jones *et al*., 2000).
- The bedrock and boulders offer surfaces for settlement and shelter of species and are colonized by encrusting and foliose red algae but dominated by animals including ascidians, bryozoans, sponges and tubicolous worms.

Productivity

- Kelp plants are major primary producers in shallow rocky marine habitats in Britain and Ireland. 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, which may enter the food chain of local subtidal ecosystems, or be exported further offshore. The Corallinaceae and foliose red algae, although not as significant as the kelp, also contribute to primary production within this biotope.
- The fast currents associated with this biotope provide a continual supply of suspended material that sustains a diverse suspension feeding community. Suspension feeders including sponges, bryozoans, ascidians and hydroids, represent the dominant fauna in this biotope highlighting the importance of secondary production.
- 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

- *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 600 m away from reproductive plants.
- Kelp plants themselves can affect recruitment in other species through their influence on the underlying substrata. Shading and mechanical sweeping, for example, will adversely affect settling larvae and post settlement survival.
- With respect to the underlying red algae, tetrasporangia from *Corallina officinalis* have been recorded throughout the year although settlement occurs after a couple of days which has the potential to limit dispersal. Recruitment in dulse, *Palmaria palmata*, is most certainly limited in terms of dispersal. Females do not release carpospores so male gametophytes produce spermatia which sink rapidly to enable the male and females gametes to come into contact for fertilization. *Lithophyllum incrustans* reproduce annually and it has been calculated that 1 mm^2 of reproductive thallus produces 17.5 million bispores per year with an average settlement of only 55 sporelings/year (Edyvean & Ford, 1984).
- The majority of characteristic fauna associated with this biotope produce planktonic larvae and therefore, depending on respective plankton durations, recruitment is possible from both local sources and populations further away. Breeding in the bryozoan *Membranipora membranacea* continues through early summer with planktonic cyphonautes settling proceeding into early autumn (Ryland & Hayward, 1977). *Spirobranchus triqueter*, a tubeworm, produces planktonic all year around, although settlement appears to be limited in winter months.

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 (see 'Recoverability'). 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 (Rinde *et al.*, 1992, cited in Birkett *et al.*, 1998). Although it was suggested that the kelp forest recovered to an almost 'normal' state within 3 to 4 years, full biological restoration after harvesting may take at least ten years (Birkett *et al.*, 1998b).

Additional information

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Preferences & Distribution

Habitat preferences

Depth Range	
Water clarity preferences	
Limiting Nutrients	Data deficient
Salinity preferences	
Physiographic preferences	
Biological zone preferences	
Substratum/habitat preferences	
Tidal strength preferences	
Wave exposure preferences	
Other preferences	Extremely sheltered from wave exposure.

Additional Information

This biotope is associated with areas of moderate to strong water flow rates. It is typically found in narrow channels, shallow lagoons/rapids or the entrances to fjordic sea lochs and to obs. In the Menai Strait and Loch Roag the biotope experiences tidal flow rates of up to 8 knots (Brazier *et al.*, 1999).

Species composition

Species found especially in this biotope

Rare or scarce species associated with this biotope

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Additional information

The MNCR recorded 425 species in 45 records of this biotope although not all the species occurred in all records of the biotope (JNCC, 1999).

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

IR.MIR.KT.LdigT occurs on very sheltered bedrock, boulders and cobbles that are subject to moderate to strong tidal steams. The community is characterized by a *Laminaria digitata* canopy, beneath which is a diverse understory community of varied red seaweed, ascidians and bryozoans. High tidal flow encourages several filter-feeding faunal groups to occur. The sponges *Leucosolenia spp.*, *Halichondria panicea* and *Hymeniacidon perleve* frequently occur on steep and overhanging faces. In addition, the ascidians *Ascidia conchilega*, *Dendrodoa grossularia* and colonial ascidians are also found.

In undertaking this assessment of sensitivity, 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, however it is recognized that the tide swept faunal community also define the biotope. Examples of important species groups are mentioned where appropriate.

Resilience and recovery rates of habitat

In general the available evidence indicates that the recovery of kelp biotopes, where kelp have been entirely removed, requires at least two years to recover. 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 $0.25m^2$ 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 by default 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 (Hoek van den *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.

Biological traits which influence the recovery rates of *Laminaria digitata* include its reproductive strategy and life history. The dispersal of *Laminaria digitata*'s 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 dependant on currents to extend their dispersal range, although the majority of larvae settle within its local habitat (Brennan *et al.*, 2014).

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 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). 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. Competition between *Laminaria digitata* and *Saccorhiza polyschides* can also increase recovery time. However, resilience has been assessed as '**High**'.

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 Spitzbergen (Birkett *et al.*, 1998; Blight & Thompson, 2008). The Northern/Boreal distribution of *Laminaria digitata* suggests it may be slightly vulnerable to temperature increases in southern examples of IR.MIR.KT.LdigT.

The thermal optimum of *Laminaria digitata* is between 10-15°C, with reproductive ability impaired to 20% at 18°C (Arzel, 1998). 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. A temperature increase to 22-23 °C causes cell damage and death (Sudene, 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, 2013). A minimum of 10 weeks a year between 5-18 °C is needed in order to ensure spore formation and hence reproduction and recruitment (Bartsch, 2013).

Combining predicted sea surface temperate over the next century with the current distribution of *Laminaria digitata*, Merzouk & Johnson (2011) predict an expansion of it's northern limits and localised extinctions across it's 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 summer sea temperature (Bartsch *et al.* 2013). In southern examples of IR.MIR.KT.LdigT, *Laminaria digitata* may also be out-competed by it's Lusitanian competitor *Laminaria ochroleuca* which is regionally abundant across the south UK coastline (Smale *et al.*, 2014).

The star ascidian *Botryllus schlosseri* and the breadcrumb sponge *Halichondria panicea* have large geographical ranges in which the UK is almost central. At the benchmark level these species are therefore likely to be tolerant of chronic temperature changes.

IR.MIR.KT.LdigT is distributed throughout the UK (Connor *et al.*, 2004). Northern to southern Sea Surface Temperature (SST) ranges from 8-16°C in summer and 6-13°C in winter (Beszczynska-Möller & Dye, 2013)

Sensitivity assessment. Northern examples of this biotope are unlikely to be affected at the benchmark level, however biotopes within the south of the UK where high summer temperatures combined with an increase of 2 & 5 °C would be above the temperature optimum of *Laminaria digitata* and may therefore cause declines in growth and abundance. Resistance has been assessed as '**Medium**', Resilience as '**High**'. Sensitivity has been assessed as '**Low**'.

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

Laminaria digitata is distributed from Brittany to the Spitzbergen (Birkett *et al.*, 1998; Blight & Thompson, 2008). The Northern/Boreal distribution of *Laminaria digitata* suggests it would tolerate a decrease in temperature at the benchmark level.

Sensitivity assessment. Resistance has been assessed as '**High**', resilience as '**High**' and sensitivity as '**Not sensitive**'.

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

Kelps are tolerant to short-term daily fluctuation in salinity; however they are much less tolerant to long-term changes with growth rates declining typically either side of 20-45 psu (Karsten, 2007). *Laminaria digitata* tolerates a large salinity range (5-60 psu; Karsen, 2007) at the extremes of this range; decreases in photosynthetic rates were evident, (Gordillo, 2002). *Laminaria digitata* is considered to be a stenohaline species, therefore this biotope is only found in conditions of full salinity (Connor et al 1997, Connor et al 2004) Axelsson & Axelsson (1987) indicated damage of the plants' plasma membranes occurs when salinity is below 20 or above 50 psu.

Sensitivity assessment. *Laminaria digitata* is unlikely to tolerate an increase to >40‰ for a year. Resistance to this pressure is considered '**Low**', and resilience as '**High**'. This biotope is considered '**Low**' to this pressure.

Salinity decrease (local)	High	High	Not sensitive
	Q: High A: High C: High	Q: High A: High C: High	Q: High A: High C: High

Birkett *et al.* (1998) suggested that kelps are stenohaline, in that they do not tolerate wide fluctuations in salinity. Growth rate may be adversely affected if the kelp plant is subjected to periodic salinity stress. 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.*, 1998).

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 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 evidence suggests that a decrease in one MNCR salinity scale from 'Full Salinity' (30-40 psu) to 'Reduced Salinity' (18-30 psu) would still be within *Laminaria digtata*'s salinity tolerance. Furthermore IR.MIR.KT.LdigT is recorded within low salinity (albeit at low occurrence), indicating many of the characterizing species can tolerate <30‰. Resistance has been assessed as '**High**' and resilience as '**High**'. Therefore, sensitivity of this biotope to a decrease in salinity has been assessed as '**Not Sensitive**'.

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

IR.MIR.KT.LdigT is recorded from very strong-very weak tidal streams (Negligible->3 m/s) (Connor *et al.*, 2004). The filter feeding community within understory community is likely dependent upon high water flow. However, the distribution of IR.MIR.KT.LdigT across a wide range of tidal streams indicates a change in water flow from 0.1-0.2 m/s would not significantly affect IR.MIR.KT.LdigT.

Sensitivity assessment. Resistance has been assessed as '**High**', resilience as '**High**'. Sensitivity has been assessed as '**Not Sensitive**' at the benchmark level.

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

Laminaria digitata biotopes are predominantly sublittoral but extend into the lower eulittoral and therefore have some ability to resist desiccation. At the sub-littoral fringe *Laminaria digitata* regularly becomes exposed to air at low water. Dring & Brown (1982) found that plants that lost up 40-50% of their initial water content were still able to return to their original photosynthetic rate on re-immersion. Many species living beneath the kelp canopy, such as *Halichondria panicea* and *Botryllus schlosseri* are also found further up the shore and are therefore likely to be tolerant to a certain degree of desiccation. Furthermore, the kelp canopy is likely to protect the algal understory and benthic fauna from the worst effects of desiccation by the kelp canopy. However, at the benchmark level, some *Laminaria digitata* plants at the upper extent of the biotope may perish from the effects of desiccation. In turn, flora and fauna in the understory may die since the canopy offers protection from desiccation, wind and insolation. The upper extent of the biotope may be reduced although this may be counteracted by an extension of the biotope at the lower limit.

Sensitivity assessment. Resilience has been assessed as '**Low**'. Resistance as '**High**'. The sensitivity of this biotope to a change in emergence is considered as '**Low**'.

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

IR.MIR.KT.LdigT is predominantly recorded from wave sheltered sites, however is also recorded up to moderate wave exposure (Connor *et al.*, 2004). 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 >0.4 m; 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 and Thomsen, 2005). A flexible stipe and low profile holdfast allows *Laminaria digitata* to flourish in moderately to strongly wave exposed areas. In areas of high wave exposure *Laminaria digitata* may extend its upper limits into the lower eulittoral zone. However, IR.HIR.KFaR.Ala.Ldig typically replaces this biotope under conditions of extreme wave exposure, while in predominantly wave sheltered and lower water flow 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 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 with adapt morphologically over time to optimise its survival in the new environment.

The associated assemblage of the biotope also influences *Laminairia digitata*'s ability to withstand increases in wave action. The epiphytic *Membranipora membranacea* 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. Wave exposure is one of the principal defining features of kelp biotopes, and large changes in wave exposure are likely to alter the relative abundance of the kelp species, grazing and understory community, and hence, the biotope. However a change in near shore significant wave height of 3-5% is unlikely to have any significant effect on IR.MIR.KT.LdigT. Resistance has been assessed as '**High**', resilience as '**High**' and sensitivity as '**Not Sensitive**' at the benchmark level.

Chemical Pressures

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

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

No information was found concerning the specific effects of transitional elements on the characterizing or important functional flora and/or fauna of IR.MIR.KT.LdigT.

The tolerance of *Laminaria digitata* to heavy metals is highly variable depending the on the metal concerned. Zinc was found to inhibit growth in *Laminaria digitata* at a concentration of 100 µg/L and at 515 µg/L, growth had almost completely ceased (Bryan, 1969). Axelsson & Axelsson (1987) investigated the effect of exposure to mercury (Hg), lead (Pb) and nickel (Ni) for 24 hours by measuring ion leakage to indicate plasma membrane damage. Inorganic and organic Hg concentrations of 1 mg/l resulted in the loss of ions equivalent to ion loss in seaweed that had been boiled for 5 minutes. *Laminaria digitata* was unaffected when subjected to Pb and Ni at concentrations up to 10 mg/l. The results also indicated that the species was intolerant of the tin compounds butyl-Sn and phenyl-Sn. 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 al.* (1999) reported that Hg was very toxic to macrophytes and Boney (1971) reported that the red algae Plumaria elegans experienced 100% growth inhibition at 1 ppm Hg. However, no information was found concerning the specific effects of heavy metals on either *Palmaria palmata* or *Corallina officinalis* or any of the important faunal components of this biotope.

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

The brown algae are thought to be largely protected from oil penetration damage by the presence of a mucilaginous coating (O'Brian & Dixon, 1976). In addition, effects of oil accumulation on the thalli are mitigated by the perennial growth of kelps. *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 strong tidal flow in this biotope may provide some protection to all seaweeds within this community. No significant effects of the Amoco Cadiz spill were observed for *Laminaria* populations and the World Prodigy spill of 922 tons of oil in Narragansett Bay had no discernible effects on *Laminaria digitata* (Peckol *et al.*, 1990). Furthermore, the upper limit of distribution for *Laminaria digitata* moved up wave exposed shores by as much as 2 m during the first few years after the Torrey Canyon oil spill due to the death of animals that graze the plants (Southward & Southward, 1978). 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).

O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil contamination. Where exposed to direct contact with fresh hydrocarbons, encrusting calcareous algae have a high intolerance. Crump *et al.* (1999) noted a dramatic bleaching on encrusting corallines and signs of bleaching in *Corallina officinalis*, *Chondrus crispus* and *Mastocarpus stellatus* at West Angle Bay, Pembrokeshire after the Sea Empress oil spill. However, encrusting corallines recovered quickly and *Corallina officinalis* was not killed. Laboratory studies of the effects of oil and dispersants on several red algae species, including *Palmaria palmata* (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. It is possible that *Corallina officinalis* and other algae are more intolerant of the dispersants used during oil spills than the oil itself. Where exposed to direct contact with fresh hydrocarbons, encrusting coralline algae appear to have a high intolerance. Crump *et al.* (1999) describe "dramatic and extensive bleaching" of '*Lithothamnia*' following the Sea Empress oil spill. Observations following the *Don Marika* oil spill (K. Hiscock, own observations) were of rockpools with completely bleached coralline algae. However, Chamberlain (1996) observed that although *Lithophyllum incrustans* was quickly affected by oil during the Sea Empress spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area.

No information was found concerning the specific effects of hydrocarbon contamination on the important faunal component of this biotope. However, the intolerance of the sponges, ascidians and bryozoans is likely to be related to depth of the oil / tar deposition and the strong tidal flow associated with this biotope is likely to reduce this. Nevertheless, analysis of kelp holdfast fauna after the Sea Empress oil spill in Milford Haven illustrated decreases in number of species, diversity and abundance at sites nearest the spill (SEEEC, 1998).

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.

Laminaria digitata along with almost all red algal species and many animal species were found to be absent from sites close to acidified, halogenated effluent from a bromide extraction plant (Hoare & Hiscock, 1974). Axelsson & Axelsson (1987) investigated the effect on *Laminaria digitata* of exposure to various chemicals for 24 hours by measuring ion leakage as an indication of plasma membrane damage. However, only limited ion loss was seen on exposure to two detergents, nonylphenol ethoxylate (NP-10) and linear alkylbenzene sulfonate (LAS). Cole *et al.* (1999) suggested that herbicides such as Simazina and Atrazine were very toxic to macrophytic algae. Laboratory studies of the effects of oil and dispersants on several red algae species, including *Palmaria palmata* (Grandy, 1984, cited in Holt *et al.*, 1995) concluded that they were all intolerant of oil/ dispersant mixtures, with little differences between adults, sporelings, diploid or haploid life stages. Smith (1968) reported that, in areas of heavy spraying of oil and detergent dispersants, *Corallina officinalis* was killed, and was affected down to a depth of 6 m in one site, presumably due to wave action and mixing. However, re-growth of fronds had begun within 2 months after spraying ceased.

Radionuclide contamination	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence

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

This pressure is **Not assessed**.

De-oxygenation	High Q: Medium A: High C: High	High Q: High A: High C: High	Not sensitive Q: Medium A: High C: High

Reduced oxygen concentrations can inhibit both photosynthesis and respiration in macroalgae (Kinne, 1977). Despite this, macroalgae are thought to buffer the environmental conditions of low oxygen, thereby acting as a refuge for organisms in oxygen depleted regions especially if the oxygen depletion is short-term (Frieder *et al.*, 2012). A rapid recovery from a state of low oxygen is expected if the environmental conditions are transient. If levels do drop below 4 mg/l negative effects on these organisms can be expected with adverse effects occurring below 2mg/l (Cole *et al.*, 1999). The understory faunal community may be affected by de-oxygenation, however IR.MIR.KT.LdigT is a tide swept biotope (Connor *et al.*, 2004) and therefore the effects of de-oxygenation are likely to be short lived.

Sensitivity Assessment. Reduced oxygen levels are likely to inhibit photosynthesis and respiration but not cause a loss of the macroalgae population directly. Resistance has been assessed as '**High**', Resilience as '**High**'. Sensitivity has been assessed as '**Not sensitive**' at the benchmark level.

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

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

High ambient levels of phosphate and nitrogen enhance spore formation in a number of *Laminaria spp.* (Nimura *et al.*, 2002), but will eventually inhibit spore production, particularly at the extremes of temperature tolerances as seen in *Saccharina latissima* (syn. *Laminaria saccharina*; Yarish *et al.*, 1990). *Laminaria digitata* seems to follow this trend with a growth peak occurring in conjunction with nutrient generation from deeper waters in Norway (Gévaert *et al.*, 2001). Despite this, enhancement of coastal nutrients is likely to favour those species with more rapid growth rates including turf forming algae (Gorgula & Connell, 2004).

Sensitivity assessment. Although nutrients may not affect kelps directly, indirect effects such as turbidity may significantly affect photosynthesis. Furthermore organic enrichment may denude the associated community. However, the biotope is probably '**Not sensitive**' (resistance is '**High**' and resilience is '**High**) at the benchmark levels (i.e. compliance with WFD criteria).

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

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

Macroalgal growth is generally nitrogen-limited in the summer, as illustrated by increased growth rates of *Laminaira digitata* in a eutrophic site when compared to an oligotrophic in Abroath, Scotland (Davison *et al.*, 1984). The deposition of sewage effluent into coastal environments resulted in the absence of *Laminaria digitata* from the coastline of the Firth of Forth (Read *et al.*, 1983) although this was probably coupled with the decrease in water clarity also observed at the time.

The use of some kelp species in conjunction with fish aquaculture (buffering the effects of organic enrichment in the local area) suggests that many commercial kelps (including *Laminaria digitata*) are tolerant to increased levels of ammonia and faecal matter, dependent on fish species and aquaculture design (Troell *et al.*, 2003).

Sensitivity assessment. Although organic enrichment may not affect kelps directly, indirect effects such as turbidity may significantly affect photosynthesis. Furthermore organic enrichment may denude the associated community. Resistance has therefore been assessed as '**Medium**', resilience as '**High**'. Sensitivity has been assessed as '**Low**'.

Physical Pressures

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

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

Physical change (to another seabed type)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

If rock substrata were replaced with sedimentary substrata this would represent a fundamental change in habitat type, which kelp species would not be able to tolerate (Birkett *et al.*, 1998). The biotope would be lost.

Sensitivity assessment. Resistance to the pressure is considered '**None**', and resilience '**Very low**' or 'None'. The sensitivity of this biotope to change from sedimentary or soft rock substrata to hard rock or artificial substrata or vice-versa is assessed as '**High'**.

Physical change (to another sediment type)	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant

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

Not relevant

Abrasion/disturbance of the surface of the substratum or seabed	None Q: Low A: NR C: NR	High Q: High A: High C: High	Medium Q: Low A: Low C: Low

Abrasion of the substratum e.g. from bottom or pot fishing gear, cable laying etc. may cause localized mortality of the resident community. The effect would be situation dependant however if bottom fishing gear were towed over a site it may cause high mortality in the resident community and potentially remove areas of the kelp.

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

Changes in suspended solids (water clarity)	Low 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.*, 1998). Light penetration influences the maximum depth at which kelp species can grow and it has been reported that laminarians grow down to depths at which the light levels are reduced to one percent of incident light at the surface. Maximal depth distribution of laminarians therefore varies from 100 m in the Mediterranean to only 6-7 m in the silt laden German Bight. In Atlantic European waters, the depth limit is typically 35 m. In very turbid waters the depth at which 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.* 1998). *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 decrease in sub-surface 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, which 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). 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 water clarity from clear to intermediate (10-100 mg/l) represents a change in light attenuation of ca 0.67-6.7 Kd/m, and is likely to result in a greater than 50% reduction in photosynthesis of *Laminaria* spp. Therefore, the dominant kelp species will probably suffer a significant decline and resistance to this pressure is assessed as '**Low**'. Resilience to this pressure is probably **High** at the benchmark. Hence, this biotope is assessed as having a sensitivity of **Low** to this pressure.

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

Laminaria digitata is more sensitive to this pressure than other subtidal brown algae (e.g. *Sargassum muticum*; Morrell & Furnhan, 1982). A layer of fine grained sediment (0.1-0.2cm thick) caused rotting of the plant and 25% mortality after 4 weeks of coverage in a laboratory experiment suggesting that in locations of low wave and current mediated water flow, sedimentation is a threat to this biotope (Lyngby & Mortensen, 1996). The abundance of filter feeders may experience some short lived interference with their feeding apparatus and respiratory flows. Furthermore, the holdfasts and lower end of the stipes of *Laminaria digitata* may experience some mild sand scour. IR.MIR.KT.LdigT is however a tide swept biotope, recorded from very strong to very weak tidal streams (negligible->3m/s). High water movement is likely to remove sediment within a couple of tidal cycles.

Sensitivity assessment. Resistance has been assessed as '**High**', resilience as '**High**'. Sensitivity has been assessed as '**Not sensitive**'.

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

Laminaria digitata is more sensitive to this pressure than other subtidal brown algae (e.g. *Sargassum muticum*; Morrell & Furnhan, 1982). A layer of fine grained sediment (0.1-0.2cm thick) caused rotting of the plant and 25% mortality after 4 weeks of coverage in a laboratory experiment suggesting that in locations of low wave and current mediated water flow, sedimentation is a threat to this biotope (Lyngby & Mortensen, 1996). The abundance of filter feeders may experience some short lived interference with their feeding apparatus and respiratory flows. Furthermore, the holdfasts and lower end of the stipes of *Laminaria digitata* may experience some mild sand scour. IR.MIR.KT.LdigT is however a tide swept biotope, recorded from very strong to very weak tidal streams (negligible->3m/s). High water movement is likely to remove sediment within a few of tidal cycles.

Sensitivity assessment. Due to the volume of deposited sediment within this pressure it is anticipated the sediment will be retained within the host habitat longer than with "light" deposition. Sediment retention may therefore inundate filter feeding fauna and cause *Laminaria digitata* mortality. Resistance has been assessed as '**Low**', resilience as '**High**'. Sensitivity has been assessed as '**Low'.**

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

Not assessed.

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

There is no evidence to suggest that anthropogenic light sources would affect *Laminaria digitata*. 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 **'Low'**, with a **'High'** resilience and a sensitivity of '**Low**', albeit with 'low' confidence due to the lack of direct evidence.

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

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

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

Not relevant

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 of *Laminaria digitata* was found. Although *Laminaria digitata* is harvested, cultivation appears to be done on wild kelp stands in a sustainable 5 year cycle (Vea and Ask, 2011), therefore, translocation of *Laminaria digitata* is unlikely. Additionally if translocation of populations does occur, a loss in genetic diversity is not regarded as an issue for *Laminaria digitata*, unless additionally pressures result in the isolation and fragmentation of wild coastal populations (Valero *et al*., 2011).

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

Sargassum muticum has been shown to competitively replace *Laminaria* spp. in Denmark (Staehr *et al*., 2000). In Nova Scotia *Codium fragile* competes successfully with native kelps for space including *Laminaria digitata*, exploitating gaps within the kelp beds, once established the algal mat created *Codium fragile* prevents re-colonization by other macro-algae (Scheibling *et al*., 2006).

Undaria pinnatifida has received a large amount of research attention as a major Invasive Non Indigenous Species (INIS) which could out-compete native UK kelp habitats (see Farrell & Fletcher, 2006; Thompson & Schiel, 2012, Brodie *et al*., 2014; Hieser *et al*., 2014). *Undaria pinnatifida* was first recorded in the UK, Hamble Estuary, in June 1994 (Fletcher & Manfredi, 1995) and has since spread to a number of British ports. *Undaria pinnatifida* is an annual species, sporophytes appear in Autumn and grow rapidly throughout winter and spring during which they can reach a length of 1.65 m (Birket *et al*., 1998). 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 *Laminariales* (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 partially due to an annual *Undaria pinnatifida* die back, which as noted by Heiser *et al.* (2014) does not occur in Plymouth sound, UK. *Undaria pinnatifida* was successfully eradicated on a sunken ship in Clatham Islands, New Zealand, by applying a heat treatment of 70°C (Wotton *et al*., 2004) however numerous other eradication attempts have failed, and as noted by Fletcher & Farrell, (1999) once established *Undaria pinadifida* resists most attempts of long-term removal. The biotope is unlikely to fully recover until *Undaria pinnatifida* is fully removed from the habitat, which 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 INIS is assessed as '**High**'.

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

Laminaria digitata may be infected by the microscopic brown alga *Streblonema aecidioides*. Infected algae show symptoms of Streblonema disease, i.e. alterations of the blade and stipe ranging from dark spots to heavy deformations and completely crippled thalli (Peters & Scaffelke, 1996). Infection can reduce growth rates of host algae.

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

Removal of target species	Low Q: High A: High C: High	High Q: High A: High C: High	Low Q: High A: High C: High

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). *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).

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). Maintaining a sustainable crop of *Laminaria digitata* has been suggested as possible if the industry continues employing small vessels evenly dispersed along the coastline. This would 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* has been indicated as a threat to the continued harvesting effort of *Laminaria digitata* (Engelen *et al*., 2011).

Sensitivity Assessment. Resistance has been assessed as **'Low**', resilience '**High**'. Sensitivity has been assessed as ‘**Low**’.

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

Incidental/accidental removal of *Laminaria digitata* as a result of non-targeted fisheries practices is likely to have a significant effect on the ecology of IR.MIR.KT.LdigT. Targeted *Laminaria hyperborea* trawling in southern Norway is reported to remove all canopy forming sporophytes (Christie *et al.* 1998).

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

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