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Information on the species and habitats around the coasts and sea of the British Isles

# *Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock with coarse sediment

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

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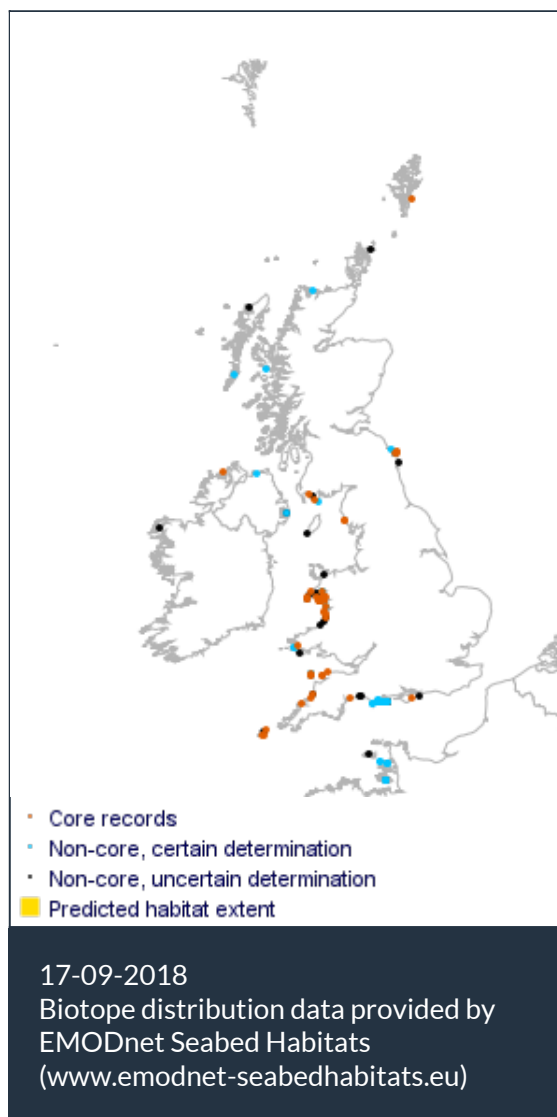
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*Halidrys* on flat pebbles and gravel.

Photographer: Rohan Holt

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Researched by Thomas Stamp and Dr Harvey Tyler-Walters

Refereed by This information is not refereed.

## Summary

### ☰ UK and Ireland classification

EUNIS 2008 A3.126

*Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock with coarse sediment

JNCC 2015 IR.HIR.KSed.XKHal

*Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock with coarse sediment

JNCC 2004 IR.HIR.KSed.XKHal

*Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock with coarse sediment

1997 Biotope IR.MIR.SedK.HalXK

*Halidrys siliquosa* and mixed kelps on tide-swept infralittoral rock with coarse sediment

### 🔍 Description

This tide-swept biotope is characterized by *Halidrys siliquosa*, which is often dense and is typically mixed with other kelps including *Saccharina latissima*, *Laminaria hyperborea* and *Saccorhiza*

*polyschides*. Below the canopy is an undergrowth of foliose red seaweeds which are tolerant of sand scour. There may be a rich epibiota on the *Halidrys siliquosa* plants, including *Aglaophenia pluma*, ascidians including *Botryllus schlosseri*, and sponges. This biotope may occur on the open coast or in rapids areas, and is distinguished from MIR.XKScrR by its greater scour. (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

### ↓ Depth range

0-5 m, 5-10 m, 10-20 m

### 🏛️ Additional information

Little information on the ecology of this biotope was found. The ecology has been inferred from general studies of subtidal macroalgal communities (see Brawley, 1992; Hawkins *et al.*, 1992; Vadas & Elner, 1992; Williams & Seed, 1992; Schiel & Foster, 1986).

### ✓ Listed By

- none -

### 🔗 Further information sources

Search on:



## Habitat review

### 🔄 Ecology

#### Ecological and functional relationships

- Macroalgae provide primary productivity either directly to grazing fish and invertebrates or indirectly, to detritivores and decomposers, in the form of detritus and drift algae or as dissolved organic material and other exudates.
- Macroalgal species compete for light, space and, to a lesser extent, nutrients, depending on the growth rates, size and reproductive pattern of each species. For example, large macroalgae such as *Halidrys siliquosa* and laminarians shade the substratum (depending on density) so that understorey plants tend to be shade tolerant red algae. Understorey algae, by effectively restricting access to the substratum, may also inhibit or restrict recruitment of other species of macroalgae (Hawkins & Harkin, 1985; Hawkins *et al.*, 1992).
- Macroalgae compete for space with sessile invertebrates such as sponges, hydroids, ascidians and bryozoans.
- *Halidrys siliquosa* and, when present, laminarians provide substratum for epiphytes, depending on location, including microflora (e.g. bacteria, blue green algae, diatoms and juvenile larger algae), *Ulothrix* and *Ceramium* sp., hydroids (e.g. *Aglaophenia pluma*, *Laomeda flexuosa*, and *Obelia* spp.), bryozoans (e.g. *Scrupocellaria* spp.), and ascidians (e.g. *Apilidium* spp., *Botryllus schlosseri*, and *Botrylloides leachi*) (Moss, 1982; Lewis, 1964, Connor *et al.*, 1997).
- Sessile epiphytes, including microflora, may reduce light available for photosynthesis and hence reduce growth and reproduction of the macroalgae, or increase drag and reduce the plants flexibility resulting in increased susceptibility to storm or wave damage (Williams & Seed, 1992).
- Amphipods, isopods and other mesoherbivores graze the epiphytic flora and senescent macroalgal tissue, which may benefit the macroalgal host, and may facilitate dispersal of the propagules of some macroalgal species (Brawley, 1992; Williams & Seed, 1992). Mesoherbivores also graze the macroalgae but do not normally adversely affect the canopy (Brawley, 1992).
- Gastropods graze epiphytes and macroalgae directly, e.g. *Steromphala cineraria*, *Lacuna vincta* and the limpet *Tectura* spp. Epiphyte grazing by *Tectura* (as *Acmaea*) sp. was reported to be important to the survival of an encrusting coralline algae (Hawkins *et al.*, 1992; Williams & Seed, 1992; Birkett *et al.*, 1998b). Where present, laminarians are probably grazed by the blue-rayed limpet *Patella pellucida*.
- Sea urchins are important general grazers (grazing drift algae, macroalgae, microalgae, and sessile fauna) in subtidal algal habitats. For example, *Echinus esculentus* has been shown to control the depth reached by *Laminaria hyperborea* biotopes in Port Erin (Kain, 1979) (see EIR.LhypR) and to significantly affect the biomass of understorey macroalgae (Schiel & Foster, 1986; Hawkins *et al.*, 1992; Vadas & Elner, 1992; Birkett *et al.*, 1998b).
- The impact of sea urchin grazing depends on density and hence depth (Hawkins *et al.*, 1992). Although *Echinus esculentus* and *Psammechinus miliaris* occur at low density in this biotope (JNCC, 1999), as evidenced by the extent of algal cover, urchin grazing probably increases the diversity of the biotope by clearing small areas for colonization by other species.
- Mobile predators include crabs (e.g. *Cancer pagurus* and *Necora puber*) feeding on small

crustaceans and gastropods, starfish such as *Asterias rubens*, and fish such as the corkwing wrasse *Crenilabrus melops*, the butterfish *Pholis gunnellus* and the dragnet *Callionymus lyra* feeding on small crustaceans, polychaetes and other invertebrates.

- Starfish (*Asterias rubens* and *Henricia oculata*), crabs and hermit crabs probably act as scavengers within the biotope.
- Epiphytic and benthic suspension feeders include bryozoans, sponges and hydroids together with tube worms (e.g. *Spirobranchus triqueter*) on boulders or *Lanice conchilega* or *Chaetopterus variopedatus* in intervening sediment, the barnacle *Balanus crenatus*, the long clawed porcelain crab *Pisidia longicornis* and the starfish *Henricia oculata*.

### Seasonal and longer term change

Little is known about temporal change in subtidal algal populations (Schiel & Foster, 1986). Most of the dominant algae within the biotope are perennial, present all year round, e.g. *Halidrys siliquosa*, *Delesseria sanguinea*, *Chondrus crispus*, *Furcellaria lumbricalis*, and *Dilsea carnosa*. However, they show seasonal variation in reproduction, with *Halidrys siliquosa*, *Furcellaria lumbricalis*, *Chondrus crispus* and *Delesseria sanguinea* releasing spores in the winter months, potentially enabling them to colonize free space opened up by increased wave action in winter storms and the dying back of annual species (see Kain, 1975). Annual species, e.g. *Chorda filum* are likely to proliferate in spring, reaching maximum abundance in summer (high insolation and temperature). Winter storms have been reported to damage *Furcellaria lumbricalis* plants (Austin, 1960b) and presumably could potentially damage or remove other members of the community, potentially opening space for colonization.

### Habitat structure and complexity

- *Halidrys siliquosa*, together with laminarians present, form an upper canopy shading the understorey algae and substratum.
- *Halidrys siliquosa*, and to a lesser extent *Saccharina latissima* when present support a diverse assemblage of epiphytes (see above). If present, *Laminaria hyperborea* may also support a diverse array of epiphytes on its stipe (see species review).
- The understorey of smaller macroalgae is dominated by a variety of sand-scour tolerant red algae, which probably varies with location. However, *Phyllophora* sp., *Chondrus crispus*, *Polyides rotunda*, *Delesseria sanguinea*, *Dilsea carnosa* and *Furcellaria lumbricalis* typically occur. The understorey includes brown seaweeds, e.g. *Dictyota dichotoma*, *Chorda filum* and *Desmarestia aculeata*.
- The surface of the substratum may support sessile invertebrates that are effective space occupiers, e.g. sponges, and barnacles (e.g. *Balanus crenatus*) and some anemones e.g. the dahlia anemone *Urticina felina*.
- The surface of boulders or cobbles support a sparse fauna of encrusting sponges (e.g. *Esperiopsis fucorum*), tubeworms (e.g. *Spirobranchus triqueter*) barnacles, crabs and ascidians (*Botryllus schlosseri*, *Clavelina lepadiformis*, and *Ascidella* spp.). The underboulder surface may support encrusting sponges, the porcelain crabs and brittlestars.
- The substratum typically includes mobile, coarse sediment (e.g. pebbles, gravel and sand), which may support burrowing polychaetes such as *Lanice conchilega* or *Chaetopterus variopedatus*.
- The interstices between understorey macroalgae may act as shelter or refuge for larvae and juveniles of the organisms found in the community (Birkett *et al.*,

1998). Laboratory evidence (Johns & Mann, 1987) suggested that Irish moss (*Chondrus crispus*) and habitat complexity attract juvenile lobster, presumably as a refuge from predation. However, Vadas & Elnor (1992) suggested that field evidence for large invertebrates or fish using macroalgal habitats as refuges or nurseries was conjectural.

## Productivity

Studies of subtidal seaweed communities in Nova Scotia suggested that seaweed annual production exceeded the consumption rates of herbivores about 10-fold. It was suggested that most of the productivity was exported in the form of suspended particulate matter (Miller *et al.*, 1971; cited in Vadas & Elnor, 1992). A large proportion of the primary productivity of seaweeds in subtidal algal stands is, therefore, probably exported in the form of drift algae (onshore or onto the strand line), particulates, exudates of dissolved organic matter, and contributes to the productivity of surrounding communities. However, no information concerning productivity within this biotope was found.

## Recruitment processes

The propagules of most macroalgae tend to settle near the parent plant (Schiel & Foster, 1986; Norton, 1992; Holt *et al.*, 1997). For example, the propagules of fucales are large and sink readily and red algal spores and gametes are immotile. Norton (1992) noted that algal spore dispersal is probably determined by currents and turbulent deposition (zygotes or spores being thrown against the substratum). For example, spores of *Ulva* sp. have been reported to travel 35km, *Phycodrys rubens* 5km and *Sargassum muticum* up to 1km, although most *Sargassum muticum* spores settle within 2m. The reach of the furthest propagule and useful dispersal range are not the same thing and recruitment usually occurs on a local scale, typically within 10m of the parent plant (Norton, 1992).

The presence of sessile invertebrates (e.g. sponges) or coralline algae, sand or sediment cover and grazing gastropods may inhibit settlement or attachment of propagules and the survival of the germlings. Fucalean algae showed greater recruitment to areas cleared of low lying algae, and coralline algae have been shown to inhibit the settlement of a number of sessile kelp forest species (Schiel & Foster, 1986). Vadas *et al.* (1992) noted that post-settlement mortality of algal propagules and early germlings was high, primarily due to grazing, canopy and turf effects, water movement and desiccation (in the intertidal) and concluded that algal recruitment was highly variable and sporadic. For example, Sousa *et al.* (1981) reported that experimental removal of sea urchins significantly increased recruitment in long-lived brown algae. In experimental plots cleared of algae and sea urchins in December, *Halidrys dioica* colonized the plots, in small numbers, within 3-4 months. Plots cleared in August received few, if any recruits, suggesting that recolonization was dependant on zygote availability and therefore the season. *Halidrys dioica* did not colonize plots grazed by urchins in their experiments (Sousa *et al.*, 1981).

When bare substratum becomes available for colonization, for instance following storm events, it is expected that algal recruitment and succession would follow a predictable sequence (Hawkins & Harkin, 1985). Initial colonizers on bare rock are often epiphytic species, suggesting that it is competition from canopy forming algae that usually restricts them to their epiphytic habit (Hawkins & Harkin, 1985). Gradually, the original canopy or turf forming species, in this case *Furcellaria lumbricalis* and *Chondrus crispus*, then become

established. These findings suggest that interactions between macrophytes are often more important than grazing in structuring algal communities (Hawkins & Harkin, 1985).

*Halidrys siliquosa* can float if detached, suggesting another potential route for dispersal. However, although some long range dispersal must occur in macroalgae (resulting in colonization of oil rigs and similar structures), van den Hoek (1987) and Norton (1992) suggested that it is probably ineffective for most species of macroalgae. Wernberg *et al.* (2001) suggested that the lack of long range dispersal success in *Halidrys siliquosa* was responsible for its regional distribution in the north east Atlantic.

Epiphytic and sessile fauna, such as sponges, hydroids, bryozoans and ascidians, have pelagic but short lived larvae with relatively short effective dispersal ranges, depending on the local hydrography. However, most epiphytic species are widespread and ubiquitous and would probably recruit rapidly from adjacent or nearby populations.

### Time for community to reach maturity

Kain (1975) noted that on a single block cleared every two months, most biomass belonged to Rhodophyceae in winter, Phaeophyceae in spring and Chlorophyceae in late summer. On blocks cleared and monitored for five years, the red algae colonized quickly and the community (including *Laminaria hyperborea*) had reached a condition similar to the pre-clearance community within 2 years and nine months (Kain, 1975). *Furcellaria lumbricalis* species grows very slowly compared to other red algae (Bird *et al.*, 1979) and takes a long time to reach maturity. For example, Austin (1960b) reported that in Wales, *Furcellaria lumbricalis* typically takes 5 years to attain fertility. This would mean that, following perturbation, recovery to a mature reproductive community would take at least 5 years. Similarly, *Halidrys siliquosa* does not reproduce until the end of its second year, and the population would therefore, take at least 2 years to begin recovery if removed. However, it grows rapidly, a maximum summer growth rate of 2cm/month being reported by Moss & Lacey (1963), so that damaged but surviving individuals would probably regain prior condition is within a year, depending on season. Recovery of *Chondrus crispus* was monitored after a rocky shore was totally denuded by ice scour in Nova Scotia, Canada, its original biomass returning within 5 years. (Minchinton *et al.*, 1997). Several furoids have been shown to recolonize cleared areas readily, especially in the absence of grazers (Holt *et al.*, 1995, 1997). For example, *Fucus* dominated areas may take 1-3 years to recolonize in British waters (Holt *et al.*, 1995).

Detailed studies in Norway by Rinde *et al.* (1992 cited in Birkett *et al.* 1998b) examined recovery of non-kelp species. The epiphyte community in control areas about 10 years old was richer and more extensive than on replacement plants in harvested areas. Of the epifauna, *Halichondria* sp. were only found on 10 year old plants and tunicates on plants 6 years post harvesting.

Overall, therefore, it is likely that the understory and large furoids such as *Halidrys siliquosa* and laminarians where present may recolonize and recover their biomass within at least 5 years. However, although epiphytic species may recruit rapidly, it may take longer (up to 10 years) for them to recover their original biomass and the biotope to return to its prior species richness.



## Additional information

None entered.

## Preferences & Distribution

### Habitat preferences

<b>Depth Range</b>	0-5 m, 5-10 m, 10-20 m
<a href="#">Water clarity preferences</a>	
<b>Limiting Nutrients</b>	Nitrogen (nitrates), Phosphorus (phosphates)
<b>Salinity preferences</b>	Full (30-40 psu)
<b>Physiographic preferences</b>	Open coast
<b>Biological zone preferences</b>	Infralittoral
<b>Substratum/habitat preferences</b>	Bedrock, Large to very large boulders, Small boulders, Cobbles, Coarse sediments
<b>Tidal strength preferences</b>	Moderately Strong 1 to 3 knots (0.5- 1.5 m/sec.), Weak < 1 knot (<0.5 m/sec.)
<b>Wave exposure preferences</b>	Moderately exposed
<b>Other preferences</b>	Sediment abrasion.

### Additional Information

*Halidrys siliquosa* dominated communities may occur below the shallow water kelp dominated belt or form extensive beds where silt accumulation prevents kelps such as *Laminaria hyperborea* or *Laminaria digitata* becoming dominant e.g. Weymouth Bay (Dixon *et al.*, 1978). *Halidrys siliquosa* dominated communities are characterized by species tolerant of silt and sediment abrasion and wave sheltered conditions but die out as the sediment substratum grain size decreases (i.e. shingle or coarse gravel) or water flow increases. However, this community is often associated with the entrance (or exit) of tidal rapids in Lochs, e.g. up to 1 -2 knots (0.5 -1m/sec) in Loch Yeor, west Uist (Lewis, 1964; Thorpe *et al.*, 1998). With increasing water flow, *Himanthalia elongata* abundance within the biotope increases. At higher water flow rates found in rapids, or increased wave action, the biotope is replaced by *Laminaria digitata* or *Laminaria hyperborea* biotopes (e.g. EIR.LhypR or MIR.Ldig.Ldig) (Lewis, 1964; Connor *et al.*, 1997a).

## Species composition

### Species found especially in this biotope

- *Aglaophenia pluma*
- *Delesseria sanguinea*
- *Dilsea carnosa*
- *Esperiopsis fucorum*
- *Halidrys siliquosa*

### Rare or scarce species associated with this biotope

-

### Additional information

The MNCR recorded ca 734 species within this biotope, although not all species occurred in all records of the biotope. *Halidrys siliquosa* dominated communities are also described by Lewis (1964) and additional records provided by Dixon *et al.* (1978).

## Sensitivity review

### Sensitivity characteristics of the habitat and relevant characteristic species

IR.HIR.KSed.XKHal is within the sediment-affected or disturbed kelp and seaweed communities (IR.HIR.KSed) habitat complex. This tide-swept biotope is characterized by a canopy of *Halidrys siliquosa*, the canopy can also be mixed with the kelps *Saccharina lattissima* (formerly *Laminaria saccharina*) and *Laminaria hyperborea*. Below the canopy the brown seaweed *Dictyota dichotoma* can be frequent mixed with scour tolerant red seaweeds, such as; *Phyllophora crispa*, *Phyllophora pseudoceranoioides*, *Rhodomela confervoides*, *Corallina officinalis* and *Chondrus crispus*. There may be a rich epibiota on the *Halidrys siliquosa* sporophytes, including *Aglaophenia pluma*, ascidians including *Botryllus schlosseri*, and sponges. The understory faunal community is not diverse, typically limited to *Spirobranchus triqueter* and other scour tolerant fauna (Connor *et al.*, 2004). The associated red algal species and invertebrates occur across a range of rock biotopes and are not considered to be key structuring or functioning species in this biotope, the sensitivity of these species is considered only generally for the sensitivity assessments.

For this sensitivity assessment, *Halidrys siliquosa* is the primary focus as the key characterizing species defining the biotope, the kelps *Saccharina lattissima* and *Laminaria hyperborea* are also considered specifically within assessments as important species to the biotope. Examples of other important species groups are mentioned where appropriate. High sediment scour and mobility is also a key environmental process which defines this biotope and limits the dominance of the kelps *Laminaria hyperborea*.

### Resilience and recovery rates of habitat

Little information concerning recruitment in *Halidrys siliquosa* was found. *Halidrys siliquosa* is a perennial brown seaweed (Pederson *et al.*, 2005) distributed across the north east Atlantic from Morocco to Northern Norway (Moss & Lacy, 1963; Algae Base, 2015). Sporophytes reach maturity in 1-2 years (Moss & Lacy, 1963). From early spring (March), germlings develop on rock substrata and undergo a period of rapid vegetative growth. Within the first year of growth, the sporophyte develops lateral branches but lacks air vesicles and reproductive structures. In the second year of growth from August to December, reproductive tissues (known as receptacles) develop and from December to March gametes are released (Moss & Lacy, 1963). Sporophytes can reach a maximum length of 120 cm (Bunker *et al.*, 2012). *Halidrys siliquosa* has comparatively large eggs (approximately 150µm in diameter) when compared to other macro-algae (Moss & Shreder, 1973), which may cause eggs to settle out and enhance local recruitment. Recovery following disturbance could, therefore, be influenced by the proximity of mature individuals producing viable eggs.

*Halidrys dioica* was shown to recruit to cleared areas within 3-4 months in the absence of sea urchins on the California coast (Sousa *et al.*, 1981). Similarly, *Halidrys siliquosa* became a dominant algae in 3 years after the removal of kelps in Norway (summary only, Svendsen, 1972). Several fucoids have been shown to recolonize cleared areas readily, especially in the absence of grazers (Holt *et al.*, 1995, 1997). For example,

Fucus dominated areas may take 1-3 years to recolonize in British waters (Holt *et al.*, 1995). Overall, *Halidrys siliquosa* is highly fecund and widespread in British waters. If a population is damaged or reduced in abundance it is likely that local recruitment will be good, especially in the winter months and prior abundance may return within a few years. Should the population be destroyed, then recruitment from the surrounding area and subsequent growth may take longer, possibly up to 5 years.

Other important algae species within IR.HIR.KSed.XKHal include; *Saccharina lattissima* (formerly *Laminaria saccharina*), *Laminaria hyperborea* and scour tolerant red seaweeds such as *Chondrus crispus*. *Saccharina lattissima* can reach maturity relatively quickly in 15-20 months (Sjøtun, 1993), however, *Laminaria hyperborea* requires 1-6 years to reach maturity (Kain, 1979; Fredriksen *et al.*, 1995; Christie *et al.*, 1998). The understory red seaweed communities are often dependant on the presence of canopy forming species, without which the understory red seaweed community may become bleached or out-competed by opportunistic annuals (Hawkins & Harkin, 1985; Jenkins *et al.*, 2004). Recovery of *Chondrus crispus* was monitored after a rocky shore was totally denuded by ice scour in Nova Scotia, Canada, its original biomass returning within 5 years, however if holdfasts remained was able to recover cover within 18 months. (Minchinton *et al.*, 1997).

The turf forming red algae may recover through repair and regrowth of damaged fronds from bases or via recolonization of rock surfaces where all the plant material is removed. All the red algae (Rhodophyta) exhibit distinct morphological stages over the reproductive life history. This phenomenon is known as heterotrichy and describes cases where the algal thallus consists of two parts; a prostrate creeping system exhibiting apical growth and functioning as a holdfast. The thalli can regrow from these crusts where they remain supporting recovery of the biotope (Mathieson & Burns, 1975; Dudgeon & Johnson, 1992). The basal crusts are perennial, tough, resistant stages that prevent other species from occupying the rock surface and allow rapid regeneration and are therefore a significant recovery mechanism.

The scour tolerant fauna such as *Spirobranchus* (syn. *Pomatoceros*) *triqueter* and *Electra pilosa* are early successional species characteristic of disturbed environments. Hiscock (1983) for example, noted that under conditions of scour and abrasion from stones and boulders moved by storms, a community consisting of fast growing species such as *Spirobranchus triqueter*. Off Chesil Bank, the epifaunal community dominated by *P. triqueter*, *B. crenatus* and *Electra pilosa*, decreased in cover in October as it was scoured away in winter storms, and was recolonized in May to June (Warner 1985). Recovery of the sparse associated fauna is considered to be 'High' for any level of impact.

**Resilience assessment.** The limited evidence suggests that *Halidrys siliquosa* may recover within 2-3 years (Moss & Lacy, 1963; Svendsen, 1972). Other important algal species such as *Saccharina lattissima* may recover within 1-2 years (Sjøtun, 1993), however, *Laminaria hyperborea* may require 1-6 years to recover if disturbed (Kain, 1979; Minchinton *et al.*, 1997). For pressures which would likely cause a significant loss of the macroalgal canopy resilience (e.g. resistance of 'None', 'Low' or 'Medium') has been assessed as 'Medium'. Where resistance is 'High', then resilience is 'High'.

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

Lüning (1984, 1990) reported an upper survival temperature of 25°C after one week exposure in *Halidrys siliquosa*. It did not survive at the higher temperatures studied. Zygote germination and growth are temperature dependent. Moss & Sheader (1973) reported 50-97% germination success at 3 and 10°C, falling considerably to 8-52% at 20°C and to zero at 22°C. Growth increased with temperature up to 20°C but germlings developed abnormally at 20°C (Moss & Sheader, 1973; Tyler-Walters, 2002).

*Halidrys siliquosa* is distributed from northern Norway to northern Portugal and also occurs in rock pools, which may experience a relatively large temperature range. Therefore, it is unlikely to be affected by long-term temperature changes within the British Isles. Short-term acute change may have adverse effects if the change increased the temperature over 20-25°C, especially if the change coincided with the release of gametes or the germination of zygotes. However, *Halidrys siliquosa* releases gametes and zygotes in the winter months (December to March).

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

The temperature isotherm of 19-20°C has been reported as limiting *Saccharina latissima* geographic distribution (Müller *et al.*, 2009). Gametophytes can develop in ≤23°C (Lüning, 1990) however the optimal temperature range for sporophyte growth is 10-15°C (Bolton & Lüning, 1982). Bolton & Lüning (1982) experimentally observed that sporophyte growth was inhibited by 50-70% at 20°C and following 7 days at 23°C all specimens completely disintegrated. In the field *Saccharina latissima* has shown significant regional variation in its acclimation to temperature changes, for example Gerard & Dubois (1988) observed sporophytes of *Saccharina latissima* which were regularly exposed to ≥20°C could tolerate these temperatures whereas sporophytes from other populations which rarely experience ≥17°C showed 100% mortality after 3 weeks of exposure to 20°C. Therefore, the response of *Saccharina latissima* to a change in temperatures is likely to be locally variable.

**Sensitivity assessment.** IR.HIR.Ksed.XKHal is distributed throughout the UK (Connor *et al.*, 2004). Northern to southern Sea Surface Temperature (SST) ranges from 8-16 °C in summer and 6-13°C in winter (Beszczynska-Möller & Dye, 2013). The effect of this pressure is likely to be regionally variable. An increase in 5°C may increase winter temperatures to above 10°C, which may negatively affect, but would not inhibit, *Halidrys siliquosa* germination. *Halidrys siliquosa* is probably tolerant to changes of

temperature in British waters. A chronic change (2°C for a year) outside the normal UK temperature range for a year may reduce *Laminaria hyperborea* recruitment and growth, and cause mass mortality of *Saccharina lattissima* ecotypes which are not acclimated to similar temperatures. Therefore, resistance has been assessed as 'Medium', Resilience as 'Medium'. Sensitivity has been assessed as 'Medium'.

Temperature decrease  
(local)

High

Q: High A: High C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: High C: High

Little information concerning the effects of low temperatures on *Halidrys siliquosa* was found. Lüning (1984, 1990) reported that it survived at 0°C for one week, and Moss & Sheader (1973) reported that the lower limit of germination was not reached at 3°C but that no gametes were released from fertile receptacles at -4°C. Overall, *Halidrys siliquosa* is recorded from northern Norway and is probably tolerant to decreases of temperature likely to occur in British waters (Tyler-Walters, 2002).

Moss & Shreader (1973) observed experimentally that *Halidrys siliquosa* germination was not affected at 3-10°C. The lower temperature limit for *Halidrys siliquosa* germination was not tested however receptacles kept at -4°C bore no viable gametes, and, therefore, the lower temperature threshold is likely to be between -4°C and 3°C.

*Laminaria hyperborea* and *Saccharina lattissima* have boreal distributions throughout the arctic. *Saccharina lattissima* and *Laminaria hyperborea* have lower temperature thresholds for sporophyte growth at 0°C (Kain 1964; Lüning, 1990). Subtidal red algae can survive at -2°C (Lüning, 1990; Kain & Norton, 1990). These temperatures are well below that considered within this pressure benchmark.

**Sensitivity assessment.** Northern to southern Sea Surface Temperature (SST) ranges from 8-16°C in summer and 6-13°C in winter (Beszczynska-Möller & Dye, 2013). Both a long-term and acute temperature decrease of 2-5°C combined with low winter temperatures are considered unlikely to have a significant effect on *Halidrys siliquosa* or *Laminariales* and is, therefore, unlikely to have a significant effect on IR.HIR.Ksed.XKHal. Resistance has been assessed as 'High', resilience as 'High'. Sensitivity has been assessed as 'Not Sensitive'.

Salinity increase (local)

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

There was limited information on the upper and lower salinity tolerances of *Halidrys siliquosa*. However, *Halidrys siliquosa* can be found growing in rock pools (Moss, 1982). High air temperatures cause surface evaporation of water from rock pools so that salinity steadily increases. The extent of temperature and salinity change is affected by the frequency and time of day at which tidal inundation occurs. If high tide occurs in early morning and evening the diurnal temperature follows that of the air, whilst high water at midday suddenly returns the temperature to that of the sea (Pyefinch, 1943). It is, therefore, likely that *Halidrys siliquosa* can tolerate hypersaline conditions, at least in the short-term however the long-term effects of hypersalinity are unknown.

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

Karsten (2007) tested the photosynthetic ability of *Saccharina latissima* under acute 2 and 5 day exposure to salinity treatments ranging from 5-60 psu. A control experiment was also carried at 34 psu. *Saccharina latissima* showed high photosynthetic ability at >80% of the control levels between 25-55 PSU. The affect of long-term salinity changes (>5 days) or salinity >60 PSU on *Saccharina latissima*' photosynthetic ability was not tested.

**Sensitivity assessment.** The evidence suggests that *Halidrys siliquosa* and *Saccharina latissima* can tolerate short exposure to hypersaline conditions of  $\geq 40\%$  (MNCR full salinity range=30-40‰), and *Laminaria hyperborea* may be more affected at long-term salinity increases. However, there is insufficient information on the hypersaline tolerance of *Halidrys siliquosa* to assess this pressure for IR.HIR.KSed.XKHal.

Salinity decrease (local)	<b>Medium</b>	<b>Medium</b>	<b>Medium</b>
	Q: Medium A: High C: High	Q: Medium A: Low C: High	Q: Medium A: High C: High

There was limited information on the upper and lower salinity tolerances of *Halidrys siliquosa*. However, *Halidrys siliquosa* has been recorded growing at 28‰ in Limfjorden, Denmark (Pederson *et al.*, 2005) but is absent further into the Baltic sea where average salinity is 7.4‰ (Meier & Kauker, 2003). *Halidrys siliquosa* can also be found growing in rock pools (Moss, 1982) Freshwater runoff and rain can cause a dilution effect within rock pools so that salinity steadily decreases. The extent of temperature and salinity change is affected by the frequency and time of day at which tidal inundation occurs. If high tide occurs in early morning and evening the diurnal temperature follows that of the air (Pyefinch, 1943). It is, therefore, likely that *Halidrys siliquosa* can tolerate hyposaline conditions, at least in the short-term, however, the long-term effects of hyposalinity are unknown.

Hopkin & Kain (1978) tested *Laminaria hyperborea* sporophyte growth at various low salinity treatments. *Laminaria hyperborea* sporophytes could grow “normally” at 19 psu, growth was reduced at 16 psu and did not grow at 7 psu. A decrease in one MNCR salinity scale from 'Full' salinity (30-40psu) to 'Reduced' salinity (18-30 PSU) would result in a decrease of *Laminaria hyperborea* sporophyte growth.

Karsten (2007) tested the photosynthetic ability of *Saccharina latissima* under acute 2 and 5 day exposure to salinity treatments ranging from 5-60 psu. A control experiment was also carried at 34 PSU. *Saccharina latissima* showed high photosynthetic ability at >80% of the control levels between 25-55 PSU. Hyposaline treatment of 10-20 PSU led to a gradual decline of photosynthetic ability. After 2 days at 5 PSU *Saccharina latissima* showed a significant decline in photosynthetic ability at approx. 30% of control. After 5 days at 5 PSU *Saccharina latissima* specimens became bleached and showed signs of severe damage. The effect of long-term salinity changes (>5 days) or salinity >60 PSU on *Saccharina latissima*' photosynthetic ability

was not tested. The experiment was conducted on *Saccharina latissima* from the Arctic, and at extremely low water temperatures (1-5°C) macroalgae acclimation to rapid salinity changes could be slower than at temperate latitudes. It is, therefore, possible that resident *Saccharina latissima* of the UK maybe be able to acclimate to salinity changes more effectively.

**Sensitivity assessment.** *Halidrys siliquosa* may tolerate minor decreases in salinity below 30-40‰ however *Halidrys siliquosa* absence from the Baltic sea combined with a lack of IR.HIR.KSed.XKHal records in “reduced salinity” (Connor et al., 2004) suggests a decrease in one MNCR salinity scale from “Full Salinity” (30-40 PSU) to “Reduced Salinity” (18-30 psu) may diminish the abundance of *Halidrys siliquosa* in IR.HIR.KSed.XKHal. Similarly, Laminariales would likely tolerate minor reductions in salinity however at the lower end of the “reduced salinity” category (e.g. 18-25psu) photosynthesis and growth may be inhibited. Resistance has been assessed as ‘None’, as the biotope would be lost if the abundance of *Halidrys siliquosa* was reduced significantly. Resilience is probably ‘Medium’. The sensitivity of this biotope to a decrease in salinity has been assessed as ‘Medium’.

**Water flow (tidal current) changes (local)**

High

Q: High A: High C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: High C: High

IR.HIR.KSed.XKHal is found from 1.5m/sec-weak tidal streams. *Halidrys siliquosa* decreases in abundance with increasing water flow, so that in tidal rapids with current speeds of 2-3 m/sec, it is replaced by *Laminaria digitata*, *Laminaria hyperborea* and *Saccorhiza polyschides* communities (Lewis, 1964; Schwenke, 1971). However, an increase of 0.1-0.2 m/s would not likely have a significant effect on IR.HIR.KSed.XKHal.

Peteiro & Freire (2013) measured *Saccharina latissima* growth from 2 sites, the first had maximal water velocities of 0.3m/sec and the second 0.1m/sec. At site 1 *Saccharina latissima* had significantly larger biomass than at site 2 (16 kg/m to 12 kg/m respectively). Peteiro & Freire (2013) suggested that faster water velocities were beneficial to *Saccharina latissima* growth. However, Gerard & Mann (1979) measured *Saccharina latissima* productivity at greater water velocities and found *Saccharina latissima* productivity is reduced in moderately strong tidal streams ( $\leq 1$ m/sec) when compared to weak tidal streams ( $< 0.5$ m/sec).

However, changes in the water flow are likely to alter the sedimentation regime and increase or decrease scour. An increase in water flow may remove the fine sand sediment and favour larger kelps typical of stable bedrock biotopes, a reduced abundance of *Halidrys siliquosa*, and result in loss of this biotope. A decrease in water flow may allow greater deposition of fine sediments, and hence increases scour, so that the biotope would be potentially replaced by IR.HIR.Ksed.XKScR. Sediment transport processes are influenced by a range of site-specific factors including local sediment supply and topography. A generic assessment is not possible and this indirect effect is not assessed for this pressure, although the siltation and changes in sediment type pressures indicate sensitivity to habitat changes. It should be noted also that wave action may also be a contributory factor with local tidal currents for sediment transport in this biotope.



**Sensitivity assessment.** An increase and/or decrease of 0.2 m/s is not likely to be significant in examples of IR.HIR.KSed.XKHal from moderate flow (0.5-1.5 m/s). A reduction in flow by 0.2 m/s may however significantly reduce flow in examples of IR.HIR.KSed.XKHal from weak flow. A decrease in tidal flow may decrease sediment scour and increase sediment stability, which may, therefore, facilitate kelps to dominate and change the biotope. A change of 0.1m/s to 0.2m/s is not likely to dramatically affect IR.HIR.KSed.XKHal structure. Resistance has been assessed as 'High', resilience as 'High'. Sensitivity has been assessed as 'Not Sensitive'.

#### Emergence regime changes

Medium

Q: Low A: NR C: NR

Medium

Q: Medium A: Low C: High

Medium

Q: Low A: Low C: Low

IR.HIR.KSed.XKHal is recorded from 0-30m Below Chart Datum (BCD) (Connor *et al.*, 2004). Shallow (0-5m) examples of this biotope may be affected by changes in emergence. An increase in emergence will increase exposure of the biotope to air and hence may increase desiccation. Therefore, the upper extent of several species within the biotope, most notably *Halidrys siliquosa*, *Saccharina latissima* and *Laminaria hyperborea* and hence the upper extent of the biotope is likely to be reduced. IR.MIR.KT.LdigT is typically found in the sublittoral fringe, at a higher tidal elevation to IR.HIR.KSed.XKHal. If IR.HIR.KSed.XKHal was elevated IR.MIR.KT.LdigT may replace IR.HIR.KSed.XKHal. Providing suitable substrata are present, IR.HIR.KSed.XKHal is likely to re-establish further down the shore within a similar emergence regime to that which existed previously.

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

#### Wave exposure changes (local)

High

Q: High A: High C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: High C: High

IR.HIR.KSed.XKHal occurs at extremely-moderately wave exposed sites (Connor *et al.*, 2004). An increase in wave exposure, from e.g. moderately exposed to exposed is likely to increase the level of scour, resulting in a change in the biotope and its potential replacement by IR.HIR.KSwed.XKScR. Similarly, a decrease in wave exposure from exposed to sheltered conditions would reduce scour and favour more sheltered kelp dominated biotope, e.g. IR.MIR.KT.XKT (Connor *et al.*, 2004). However, an increase in nearshore significant wave height of 3-5% is not likely to have a significant effect on biotope structure.

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

### Chemical Pressures

#### Transition elements & organo-metal contamination

Resistance

Not Assessed (NA)

Q: NR A: NR C: NR

Resilience

Not assessed (NA)

Q: NR A: NR C: NR

Sensitivity

Not assessed (NA)

Q: NR A: NR C: NR

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

Holt *et al.* (1995, 1997) reported that fucoids and other algae were capable of retaining and concentrating heavy metals, so much so that *Fucus* spp. are used as indicators of heavy metal pollution. Alginates found in fucoids (and in *Halidrys siliquosa*) strip heavy metals and some radionuclides from seawater and store them in inert forms. Hence, adult plants are considered to be relatively tolerant of heavy metal contamination. However, younger stages may be more intolerant. For example iron ore dust interfered with the interaction between eggs and sperm in *Fucus serratus* (Boney, 1980; cited in Bryan, 1984). Bryan (1984) also reported that heavy metals retarded growth in brown algae and 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. Heavy metals have been shown to effects on sporophyte development, growth and respiration in *Laminaria hyperborea* (Hopkin & Kain, 1978) and in *Laminaria digitata* (Axelsson & Axelsson, 1987).

Cole *et al.* (1999) suggested that Cd was very toxic to Crustacea (amphipods, isopods, shrimp, mysids and crabs), and Hg, Cd, Pb, Cr, Zn, Cu, Ni, and As were very toxic to fish. Bryan (1984) reported sub-lethal effects of heavy metals in crustaceans at low (ppb) levels. Bryan (1984) suggested that polychaetes are fairly resistant to heavy metals, based on the species studied. short-term toxicity in polychaetes was highest to Hg, Cu and Ag, declined with Al, Cr, Zn and Pb whereas Cd, Ni, Co and Se were the least toxic. However, he suggested that gastropods were relatively tolerant of heavy metal pollution.

#### 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.

IR.HIR.KSed.XKHal is protected from the direct effects of oil spills due to its subtidal habit, although it may be exposed to water soluble components of the oil or oil adsorbed on to particulates. No information concerning the effects of oil on *Halidrys siliquosa* was found. However, Holt *et al.* (1997) suggested that other fucoids, e.g. *Fucus* sp. had limited intolerance to oil but noted that studies on long-term exposure were limited. *Saccharina latissima* (studied as *Laminaria saccharina*) was observed to show no discernible effects from oil spills, largely due to poor dispersion into the water column and high levels of dilution (Holt *et al.*, 1995).

O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil or dispersant contamination, possibly due to the susceptibility of phycoerythrins to destruction. Laboratory studies of the effects of oil and dispersants on several red algal species, including *Delesseria sanguinea* and *Plocamium cartilagineum*, concluded that they were all sensitive to oil/ dispersant mixtures, with little difference between adults, sporelings, diploid or haploid life stages (Grandy, 1984; cited in Holt *et al.*, 1995). long-term effects of continuous doses of the water accommodated fraction (WAF) of diesel oil were determined in experimental mesocosms (Bokn *et al.*, 1993). Mean hydrocarbon concentrations tested were 30.1 µg/l and 129.4 µg/l. After 2 years, there were no demonstrable differences in the

abundance patterns of *Chondrus crispus*. Kaas (1980; cited in Holt *et al.*, 1995) reported that the reproduction of adult *Chondrus crispus* plants on the French coast was normal following the *Amoco Cadiz* oil spill. However, it was suggested that the development of young stages to adult plants was slow, with biomass still reduced 2 years after the event. O'Brien & Dixon (1976) also noted that hydrocarbon exposure reduced photosynthesis in algae.

Oil spills and hydrocarbon exposure in the intertidal results in loss of gastropod or crustacean grazers (Southward, 1982; Suchanek, 1993). Loss of grazers may allow development of more ephemeral green algae and a change in the algal community. However, although Bokn *et al.* (1993) could not demonstrate direct effects of chronic hydrocarbon contamination in their mesocosms, they concluded that chronic effects of oil on *Littorina littorea* and perhaps other herbivores may require more than 2 years to develop.

**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.

Fucoids, are generally quite robust in terms of chemical pollution (Holt *et al.*, 1995, 1997), e.g. *Fucus* sp. seem to thrive in TBT-polluted waters (Bryan & Gibbs, 1991). However, Rosemarin *et al.* (1994) stated that brown algae (Phaeophycota) were extraordinarily intolerant of chlorate, such as from pulp mill or brine electrolysis effluents (Holt *et al.*, 1997). O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil or dispersant contamination, possibly due to the susceptibility of phycoerythrins to destruction. They also reported that red algae are effective indicators of detergent damage since they undergo colour changes when exposed to relatively low concentration of detergent. Smith (1968) reported that 10 ppm of the detergent BP 1002 killed the majority of specimens in 24hrs in toxicity tests, although *Ahnfeltia plicata* and *Chondrus crispus* were amongst the algal species least affected by the detergent used to clean up the Torrey Canyon oil spill. Laboratory studies of the effects of oil and dispersants on several red algal species, including *Plocamium cartilagineum*, concluded that they were all sensitive to oil/dispersant mixtures, with little difference between adults, sporelings, diploid or haploid life stages (Grandy, 1984; cited in Holt *et al.*, 1995). Cole *et al.* (1999) suggested that herbicides in urban or agricultural runoff, such as simazine and atrazine, were very toxic to macrophytes. Hoare & Hiscock (1974) noted that all red algae except *Phyllophora* sp. were excluded from Amlwch Bay, Anglesey, by acidified halogenated effluent discharge. The evidence suggests that in general red algae are very intolerant of synthetic chemicals. Crustacean members of the fauna (mesoherbivores) are likely to be intolerant of pesticides, such as ivermecten, dichlorvos and synthetic pyrethroids (Cole *et al.*, 1999), the exact toxicity varying with location (concentration) and species. Ascidian larval stages were reported to be intolerant of TBT (Mansueto *et al.*, 1993 cited in Rees *et al.*, 2001). Rees *et al.* (1999; 2001) reported that the epifauna of the inner Crouch estuary had largely recovered within 5 years (1987-1992) after the ban on the use of TBT on small boats in 1987. Increases in the abundance of *Ascidia* sp. and *Ciona intestinalis* were especially noted.

<b>Radionuclide contamination</b>	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
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No evidence was found.

<b>Introduction of other substances</b>	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
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This pressure is **Not assessed**.

<b>De-oxygenation</b>	High Q: Medium A: High C: High	High Q: Medium A: High C: High	Not sensitive Q: Medium A: High C: High
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Reduced oxygen concentrations can inhibit both photosynthesis and respiration in macroalgae (Kinne, 1977). Despite this, macroalgae are thought to buffer the environmental conditions of low oxygen, thereby acting as a refuge for organisms in oxygen depleted regions especially if the oxygen depletion is short-term (Frieder *et al.*, 2012). A rapid recovery from a state of low oxygen is expected if the environmental conditions are transient. If levels do drop below 4 mg/l negative effects on these organisms can be expected with adverse effects occurring below 2mg/l (Cole *et al.*, 1999).

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

<b>Nutrient enrichment</b>	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not sensitive Q: NR A: NR C: NR
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This biotope is considered 'Not sensitive' at the pressure benchmark that assumes compliance with good status as defined by the WFD.

Wernberg *et al.* (2001) reported that the N:P (nitrogen to phosphorus) ratio in Limfjorden *Halidrys siliquosa* was low in summer and high in spring, which suggested that growth was nutrient limited by P in spring and N in summer. Kindig & Littler (1980) exposed *Halidrys dioica* and other algae to 10% untreated sewage effluent in the field, which resulted in increased gross productivity. However, *Halidrys dioica* was found to be absent in the vicinity of a sewage outfall, and Kindig & Littler (1980) concluded that another component of the effluent, other than nutrient, was responsible. Overall, therefore, it would appear that moderate nutrient enrichment at the benchmark level may stimulate growth of *Halidrys spp.* However, excessive enrichment may lead to eutrophication, decreased oxygen levels (see relevant pressure) and the potential smothering of *Halidrys sp.* by microfloral epiphytes (Tyler-Walters, 2002).

Bokn *et al.* (2003) conducted a nutrient loading experiment on intertidal fucoids. Within 3 years of the experiment no significant effect was observed in the communities, however, 4-5 years into the experiment a shift occurred from

perennials to ephemeral algae. The results within Bokn *et al.* (2003) could indicate that long-term (>4 years) nutrient loading can result in community shift to ephemeral algae species.

Conolly & Drew (1985) found *Saccharina latissima* sporophytes had relatively higher growth rates when in close proximity to a sewage outlet in St Andrews, UK when compared to other sites along the east coast of Scotland. At St Andrews nitrate levels were 20.22  $\mu\text{M}$ , which represents an approx 25% increase when compared to other comparable sites (approx 15.87  $\mu\text{M}$ ). Handå *et al.* (2013) also reported *Saccharina latissima* sporophytes grew approx 1% faster per day when in close proximity to Norwegian Salmon farms, where elevated ammonium could be readily absorbed by sporophytes. Read *et al.* (1983) reported after the installation of a new sewage treatment works which reduced the suspended solid content of liquid effluent by 60% in the Firth of Forth, *Saccharina latissima* became abundant where previously it had been absent.

Johnston & Roberts (2009) conducted a meta-analysis, which reviewed 216 papers to assess how a variety of contaminants (including sewage and nutrient loading) affected 6 marine habitats (including subtidal reefs). A 30-50% reduction in species diversity and richness was identified from all habitats exposed to the contaminant types. Johnston & Roberts (2009) however also highlighted that macroalgal communities are 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). Organic enrichment may also result in phytoplankton blooms that increase turbidity and, therefore, may negatively impact photosynthesis.

#### Organic enrichment

Medium

Q: Medium A: Medium C: High

Medium

Q: Medium A: Medium C: High

Medium

Q: Medium A: Medium C: High

Bokn *et al.* (2003) conducted a nutrient loading experiment on intertidal fucoids. Within 3 years of the experiment, no significant effect was observed in the communities, however, 4-5 years into the experiment a shift occurred from perennials to ephemeral algae.

Conolly & Drew (1985) found *Saccharina latissima* sporophytes had relatively higher growth rates when in close proximity to a sewage outlet in St Andrews, UK when compared to other sites along the east coast of Scotland. Read *et al.* (1983) reported after the installation of a new sewage treatment works which reduced the suspended solid content of liquid effluent by 60% in the Firth of Forth, *Saccharina latissima* became abundant where previously it had been absent.

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enrichment may also result in phytoplankton blooms that increase turbidity and, therefore, may negatively impact photosynthesis.

**Sensitivity assessment.** Conflicting evidence suggests that organic enrichment does not directly negatively affect macro-algae, however, organic enrichment could increase water turbidity and long-term exposure could cause a shift from perennial to ephemeral algae. Resistance has been assessed as '**Medium**' due to potential changes in community composition, resilience as '**Medium**'. Sensitivity has been assessed as '**Medium**'.

## A Physical Pressures

	Resistance	Resilience	Sensitivity
Physical loss (to land or freshwater habitat)	<b>None</b> Q: High A: High C: High	<b>Very Low</b> Q: High A: High C: High	<b>High</b> 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)	<b>None</b> Q: High A: High C: High	<b>Very Low</b> Q: High A: High C: High	<b>High</b> Q: High A: High C: High
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If rock substrata were replaced with sedimentary substrata this would represent a fundamental change in habitat type, which macro-algae would not be able to tolerate. 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 to a sedimentary or soft rock substrata or artificial substrata 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
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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
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Not relevant to rock substrata.

Abrasion/disturbance of the surface of the substratum or seabed	<b>None</b> Q: Low A: NR C: NR	<b>Medium</b> Q: Medium A: High C: High	<b>Medium</b> Q: Low A: Low C: Low
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The biotope is characterized by abrasion in the form of scour from mobile coarse sediment, so that members of the community are probably resistant to or recover quickly from low level abrasion (e.g. potting) But abrasion of the substratum e.g. from bottom fishing gear, cable laying etc. may cause localised mobility of the substrata (e.g. pebbles, cobbles and boulders) and mortality of the resident community. The effect would be situation dependent however if bottom fishing gear were towed over a site it may mobilise a high proportion of the rock substrata and cause high mortality in the resident community.

No specific examples of anthropogenic abrasion could be found for this biotope. However, bottom fishing gear (e.g. scallop dredging) are known to cause high mortality in bycatch species by overturning sediment with resultant reductions in biodiversity (Bradshaw *et al.*, 2001).

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

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

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

<b>Changes in suspended solids (water clarity)</b>	<b>Medium</b>	<b>Medium</b>	<b>Medium</b>
	Q: Medium A: Medium C: Medium	Q: High A: High C: High	Q: Medium A: Medium C: Medium

Suspended Particle Matter (SPM) concentration has a negative linear relationship with sub surface light attenuation (Kd) (Devlin *et al.*, 2008). Moss & Shreader (1973) noted that *Halidrys siliquosa* has comparatively large eggs (approximately 150µm in diameter) and may, therefore, have comparatively large energy stores, enabling germination and early growth to occur in total darkness. Moss & Shreader (1973) noted germling development could continue in darkness for a period of 40 days, beyond which development ceased. Germlings exposed to darkness for a period of 120 days but were returned to full light resumed normal growth, beyond 120 days of darkness the number of surviving germlings fell rapidly. However, light availability and water turbidity are principal factors in determining depth range at which macroalgae can be found (Birkett *et al.*, 1998).

Light penetration influences the maximum depth at which *Laminarians* 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 100m in the Mediterranean to only 6-7m in the silt laden German Bight. In Atlantic European waters, the depth limit is typically 35m. 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). *Laminarians* 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).

**Sensitivity assessment.** An increase in water clarity from clear to intermediate (10-100 mg/l) represent a change in light attenuation of ca 0.67-6.7 Kd/m, and is likely to result in a greater than 50% reduction in photosynthesis of *Laminaria* spp. Therefore, the dominant kelp species will probably suffer a severe decline and resistance to this pressure is assessed as **Medium** at the benchmark. Resilience is probably **Medium**, hence, this biotope is regarded as having a sensitivity of Medium to this pressure.

Smothering and siltation rate changes (light) **High**

Q: Low A: NR C: NR

**High**

Q: High A: High C: High

**Not sensitive**

Q: Low A: Low C: Low

Smothering by sediment e.g. 5 cm material during a discrete event, is unlikely to damage mature *Halidrys siliquosa* or *Laminaria hyperborea* and *Saccharina latissima* sporophytes but may provide a physical barrier to settlement and could therefore negatively impact recruitment processes (Moy & Christie, 2012). Due to their small size newly settled zoospores could be inundated with sediment, however, laboratory studies have shown that newly settled *Halidrys siliquosa* can survive and develop in darkness for 120 days (4.6 months) (Moss & Shreader, 1973) and kelp gametophytes for 6-16 months at 8°C (Dieck, 1993). However, IR.HIR.KSed.XKHal is recorded from moderately wave exposed sites (Connor *et al.*, 2004). Deposited sediments are unlikely to remain for more than a few tidal cycles (due to water flow or wave action).

**Sensitivity assessment.** This biotope is characterized by scour by coarse sediments, and fine sediments are likely to be removed quickly. Therefore, resistance has been assessed as 'High', resilience as 'High'. Sensitivity has been assessed as 'Not Sensitive'. Please note sedimentation could result in an increase in local sediment scour and/or de-oxygenation, please see relevant pressure sections for specific reviews.

Smothering and siltation rate changes (heavy) **High**

Q: Low A: NR C: NR

**High**

Q: High A: High C: High

**Not sensitive**

Q: Low A: Low C: Low

Smothering by sediment e.g. 30 cm material during a discrete event, is unlikely to damage mature *Halidrys siliquosa* or *Laminaria hyperborea* and *Saccharina latissima* sporophytes but may provide a physical barrier to settlement and could therefore negatively impact on recruitment processes (Moy & Christie, 2012). Due to their small size newly settled zoospores could be inundated with sediment, however, laboratory studies have shown that newly settled *Halidrys siliquosa* can survive and develop in darkness for 120 days (4.6 months) (Moss & Shreader, 1973) and kelp gametophytes for 6-16 months at 8°C (Dieck, 1993). IR.HIR.KSed.XKHal is recorded from extreme-moderately wave exposed sites (Connor *et al.*, 2004). Deposited sediment are unlikely to remain for more than a few tidal cycles (due to water flow or wave action). However, IR.HIR.KSed.XKHal is recorded from extreme-moderately wave exposed sites (Connor *et al.*, 2004). Deposited sediment are unlikely to remain for more than a few tidal cycles (due to water flow or wave action).

**Sensitivity assessment.** This biotope is characterized by scour by coarse sediments, and fine sediments are likely to be removed quickly. Therefore, resistance has been assessed as 'High', resilience as 'High'. Sensitivity has been assessed as 'Not



**Sensitive**. Please note sedimentation could result in an increase in local sediment scour and/or de-oxygenation, please see relevant pressure sections for specific reviews.

<b>Litter</b>	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			
<b>Electromagnetic changes</b>	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			
<b>Underwater noise changes</b>	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			
<b>Introduction of light or shading</b>	Low Q: Low A: NR C: NR	Medium Q: Low A: NR C: NR	Medium Q: Low A: Low C: Low

There is no evidence to suggest that anthropogenic light sources would affect macro-algae. Shading (e.g. by the construction of a pontoon, pier etc) could adversely affect IR.HIR.KSed.XKHal 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 seaweed abundance.

Moss & Shreader (1973) noted throughout experimentation that *Halidrys siliquosa* germination was not affected by darkness, however also commented that *Halidrys siliquosa* has comparatively large eggs (approximately 150µm in diameter) and may, therefore, have comparatively large energy stores, enabling germination and early growth to occur in total darkness. Moss & Shreader (1973) noted germling development could continue in darkness for a period of 40 days, beyond which development ceased. Germlings exposed to darkness for a period of 120 days but were returned to full light resumed normal growth, beyond 120 days of darkness the number of surviving germlings fell rapidly.

**Sensitivity assessment.** Resistance is probably 'Low', with a 'Medium' resilience and a sensitivity of 'Medium', albeit with 'low' confidence due to the lack of direct evidence.

<b>Barrier to species movement</b>	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
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**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.

<b>Death or injury by collision</b>	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR
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**Not relevant.** Collision from grounding vessels is addressed under abrasion above.

<b>Visual disturbance</b>	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR
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Not relevant

## Biological Pressures

	<b>Resistance</b>	<b>Resilience</b>	<b>Sensitivity</b>
<b>Genetic modification &amp; translocation of indigenous species</b>	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR	<b>Not relevant (NR)</b> Q: NR A: NR C: NR

At the time of writing there is no evidence of genetic modification and/or translocation of *Halidrys siliquosa*, *Laminaria hyperborea* or *Saccharina latissima* over significant geographic distances. The pressure is therefore considered '**Not relevant**' to IR.HIR.KSed.XKHal.

<b>Introduction or spread of invasive non-indigenous species</b>	<b>Low</b> Q: High A: High C: High	<b>Very Low</b> Q: High A: High C: High	<b>High</b> Q: High A: High C: High
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The Invasive Non-Indigenous Species (INIS) *Sargassum muticum* was introduced to Europe in the last 30-40 years and has since become a permanent component of macroalgal communities (Pederson *et al.*, 2005). Limfjorden a shallow Danish Fjord has been used for numerous studies on the ecological impacts of *Sargassum muticum* on native macroalgae communities, with particular emphasis on *Halidrys siliquosa* (See: Staehr *et al.*, 2000; Wernberg *et al.*, 2004; Pedersen *et al.*, 2005). First introduced to Limfjorden, Denmark in 1984 *Sargassum muticum* has since colonized approximately 35% of rocky substrata (between 0-6m BCD) and is associated with the local decline/replacement of native macro-algae species, including *Halidrys siliquosa* (Staehr *et al.*, 2000; Wernberg *et al.*, 2004; Pederson *et al.*, 2005). Wernberg *et al.* (2004) observed seasonal variation however the macro-algae epi-biota communities of Limfjorden, Denmark were not significantly affected by the introduction of *Sargassum muticum*, and may even have increased the local abundance of epi-biota species. Thus the introduction of *Sargassum muticum* to Limfjorden, Denmark has likely resulted in a dramatic decline of resident *Halidrys siliquosa* and thus fundamentally changed biotope structure (Pederson *et al.*, 2005), however, the associated epi-biota community is seemingly un-affected.

**Sensitivity assessment.** Resistance to the pressure is considered '**Low**' and resilience '**Very low**' (as biotope recovery will not occur unless the INIS is removed. The

sensitivity of this biotope to the introduction of invasive non-indigenous species is assessed as 'High'.

**Introduction of microbial pathogens**    **Not relevant (NR)**    **Not relevant (NR)**    **No evidence (NEv)**  
 Q: NR A: NR C: NR    Q: NR A: NR C: NR    Q: NR A: NR C: NR

Little information was found regarding diseases in macroalgae. *Halidrys siliquosa* supports a number of epiphytic species, which use it as a substratum but are not parasitic on the plant (Connor *et al.*, 1997). Growth rates of *Saccharina latissima* may be reduced by Streblonema disease (Lein *et al.*, 1991). There was, however, insufficient evidence to assess this pressure on IR.HIR.KSed.XKHal.

**Removal of target species**    **Low**    **Medium**    **Medium**  
 Q: Low A: NR C: NR    Q: High A: High C: High    Q: Low A: Low C: Low

*Halidrys siliquosa* extracts are used within skin beauty products (Gelyma, 2015), however at the time of writing information regarding large scale extraction of *Halidrys siliquosa* from the seabed is lacking. There has been recent commercial interest in *Saccharina lattissima* as a consumable called "sea vegetables" (Birket *et al.*, 1998). However, *Saccharina lattissima* sporophytes are typically matured on ropes (Handå *et al.*, 2013) and not directly extracted from the seabed, as with *Laminaria hyperborea* which is commercial trawled for alginate across the North Atlantic (Christie *et al.*, 1998). *Chondrus crispus* is extracted commercially in Ireland, but the harvest has declined since its peak in the early 1960s (Pybus, 1977). The effect of harvesting has been best studied in Canada. Sharp *et al.* (1986) reported that the first drag rake harvest of the season on a Nova Scotian *Chondrus crispus* bed removed 11% of the fronds and 40% of the biomass. Efficiency declined as the harvesting season progressed. Chopin *et al.* (1988) noted that non-drag raked beds of *Chondrus crispus* in the Gulf of St Lawrence showed greater year round carposporangial reproductive capacity than a drag raked bed. Commercial exploitation of the red seaweeds which characterize the biotope has the potential to impact the community greatly, through changes in community structure and physical disturbance of the other species present.

**Sensitivity assessment.** Evidence to assess the resistance of IR.HIR.KSed.XKHal to direct harvesting is limited. Neither kelp species nor *Chondrus crispus* are likely to be significantly abundant within IR.HIR.KSed.XKHal to attract commercial interest, however if targeted removal of macro-algae was initiated within IR.HIR.KSed.XKHal It has been assumed that operations would remove >75% of canopy forming sporophytes. Resistance has been assessed as 'Low', Resilience as 'Medium'. Sensitivity has been assessed as 'Medium'.

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

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The sensitivity assessment for this pressure considers any biological/ecological effects resulting from the removal of non-target species on this biotope. Incidental removal of the key characterizing species and

associated species would alter the character of the biotope. The biotope is characterized by a macroalgal canopy of *Halidrys siliquosa* mixed with other brown seaweeds, including the kelps *Saccharina lattissima* and *Laminaria hyperborea*. These provide a canopy under which a variety of red seaweeds grow, as well as attachment surfaces for epiphytic species. The loss of the canopy due to incidental removal as by-catch would, therefore, alter the character of the habitat and result in the loss of species richness. The ecological services such as primary and secondary production provided by these species would also be lost.

Low level disturbances (e.g. solitary anchors) are unlikely to cause harm to the biotope as a whole, due to the impact's small footprint. Thus evidence to assess the resistance of IR.HIR.KSed.XKHal to non-targeted removal is limited. It is assumed that incidental non-targeted catch will mobilise sediment and cause high mortality within the affected area.

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

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