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Alaria esculenta on exposed sublittoral fringe bedrock

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

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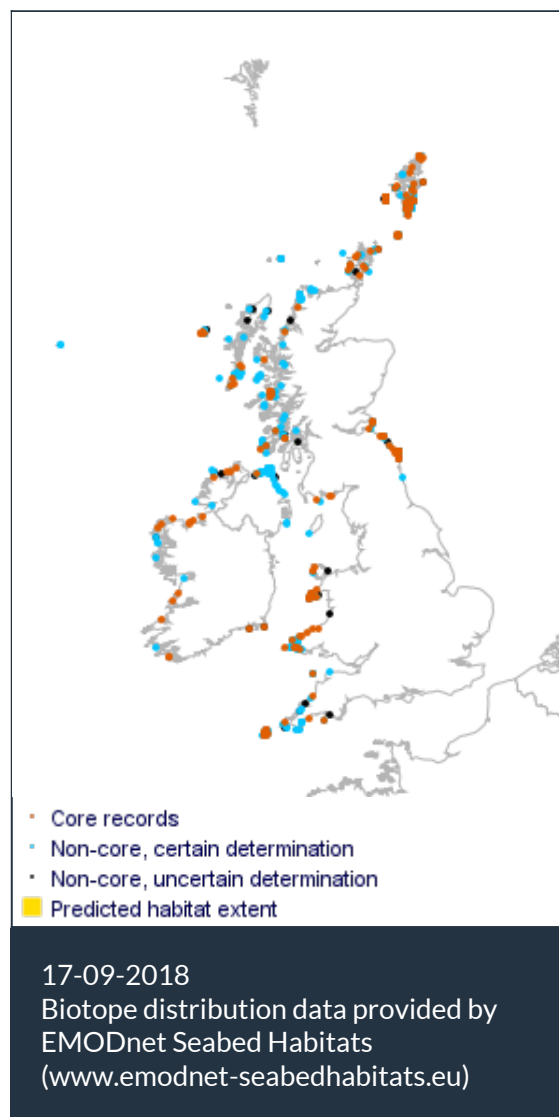


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Alaria esculenta on exposed sublittoral fringe bedrock
 Photographer: Keith Hiscock
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Researched by Thomas Stamp and Dr Harvey Tyler-Walters

Refereed by Dr Tim Hill

Summary

☰ UK and Ireland classification

EUNIS 2008 A3.111 *Alaria esculenta* on exposed sublittoral fringe bedrock

JNCC 2015 IR.HIR.KFaR.Ala *Alaria esculenta* on exposed sublittoral fringe bedrock

JNCC 2004 IR.HIR.KFaR.Ala *Alaria esculenta* on exposed sublittoral fringe bedrock

1997 Biotope IR.EIR.KFaR.Ala *Alaria esculenta* on sublittoral fringe bedrock

🔍 Description

Alaria esculenta forest on exposed sublittoral fringe bedrock with an encrusting fauna of mussels and barnacles. The rock surface is covered with encrusting coralline red algae. Two variants of this biotope are described. The more wave exposed of the two lacks *Laminaria digitata* and is also characterized by patches of mussels (EIR.Ala.Myt). The other variant is slightly less exposed and is characterized by a mixture of *Alaria esculenta* and *Laminaria digitata* (EIR.Ala.Ldig). (Information from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a,

b).

↓ Depth range

Lower shore, 0-5 m

Additional information

This review of IR.HIR.KFaR.Ala represents the sensitivity of the sub-biotope and similar biotopes IR.HIR.KFaR.Ala.Myt, IR.HIR.KFaR.Ala.Ldig, IR.HIR.KFaR.AlaAnCrSp.

✓ Listed By

- none -

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Ecological and functional relationships

- *Alaria esculenta* is able to out-compete other Laminarians in wave exposed sublittoral fringe due to its rapid growth rate and ability to withstand wave exposed conditions. It is particularly successful in exposed areas due to its flexible stipe and narrow, streamlined, blade.
- Grazers are relatively rare in the sublittoral fringe and canopy interactions may be the most important structuring agency (Hawkins & Hartnoll 1985). The sweeping action of *Laminaria digitata*, and presumably *Alaria esculenta*, in wave exposed conditions prevents colonization by ephemeral algae by abrasion (Hawkins & Hartnoll 1985).
- The understory is dominated by encrusting corallines and *Corallina officinalis* turf. In wave exposed sites the erect coralline turf grows very compactly reducing the interstitial space (exacerbated by presence of small Mytilids) and affecting the interstitial fauna. Dommanes (1968) showed that the coralline turf fauna varied with wave exposure. Wave exposed sites were dominated by amphipods and short legged isopods capable of grasping the fronds firmly. Interstitial fauna consists of grazers and suspension feeders (Dommanes 1968) that probably remove ephemeral algae and epiphytes from *Corallina officinalis*.
- On Rockall, the extreme wave exposure results in *Alaria esculenta* forest dominating both the sublittoral and infralittoral zone in the deeper areas. In the Rockall *Alaria* forest the holdfasts of *Alaria esculenta* become covered in a thick layer of encrusting coralline algae and, after the death of the alga, the holdfast rots leaving a space under the coralline crust that is a habitat for several mobile species that would most likely not survive on the open rock in such a wave exposed situation (K. Hiscock, pers. Comm.).
- Barnacle species are suspension feeders, that probably take algal spores and larvae that would otherwise settle within the community. Birkett *et al.* (1998b) point out that active suspension feeding by *Mytilus edulis* probably removes large numbers of settling algal spores and also compete for space. However in the wave exposed sublittoral fringe, the small size of individual mytilids suggests that larger individuals are removed by wave action.
- Patellids are active grazers, however, they lack the necessary enzymes to digest Laminarian tissue (Birkett *et al.* 1998b) and probably do not graze *Alaria esculenta* extensively. However, they probably graze other algae and are important in keeping coralline turf and encrusting corallines free of ephemeral algae. Grazing activity of patellids probably remove *Alaria esculenta* and other kelp germlings as the limpets pass over them; a bulldozing effect (T. Hill pers. Comm.).
- 2 years). *Laminaria digitata* was cleared from moderately wave exposed concrete blocks at Port Erin, Isle of Man, and the subsequent "succession" of algae communities was documented. Following clearance *Laminaria digitata* was considered re-established two years after removal, while the understory red seaweed species returned one year later. Engelen (2010) observed a similar recovery time in Brittany, France. Patches of *Laminaria digitata* (0.25m²) were removed.. *Laminaria digitata* returned to conditions prior to removal within 18-24 months, although competition for space by *Saccorhiza polyschides* reduced recovery rates in the first year of recolonization. Engelen (2010) stated that *Laminaria digitata* forest recovery rates varied between seasons, with autumn recovery

being more rapid than spring (taking a minimum of 12 months).

The dispersal of *Laminaria digitata*'s spores and subsequent successful recruitment has been recorded 600 m from reproductive individuals (Chapman, 1981). 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 Lamina (blade; Kain, 1979). Zoospores 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. Furthermore, experimental clearance experiments of *Laminaria digitata* (Kain 1975; Hawkins & Harkin 1985; Hill 1993; Engelen, 2010) found that following clearance *Laminaria digitata* re-colonization takes 12-24 months. Interspecific competition from ephemeral algae was also found to slow recovery times (Engelen, 2010).

Corallina officinalis produces spores over a protracted period and can colonize artificial substratum within one week in the intertidal (Harkin & Lindbergh 1977; Littler & Kauker 1984). The crustose base enables *Corallina officinalis* to survive extreme wave exposure and damage (loss of fronds), and to take advantage (colonize) of space left after winter storms have removed competing macroalgae (Littler & Kauker 1984). The mobile interstitial fauna of the coralline turf is reduced by trampling (Brown & Taylor 1989) but is likely to recruit to or recolonize the turf from the surrounding communities. Encrusting and erect corallines are also known to stimulate the settlement of a variety of marine invertebrate larvae and algal spores. *Corallina officinalis* is capable of colonizing new substratum rapidly. In experimental plots, 15 percent cover of fronds returned within 3 months (Littler & Kauker 1985) and Brown & Taylor (1999) noted that the articulated coralline algal turf community on a New Zealand shore returned to normal levels within 3 months of trampling events, although they suggested that a return to its previous cover may take longer.

Resilience assessment. *Alaria esculenta* is an opportunistic and rapidly colonizing species (see above) capable of growing 20 cm/month in optimal conditions, reaching maturity within 10-14 months, and often appearing early in the algal succession (c. 3 months after clearance of dominant algae). In canopy removal experiments in the Isle of Man, Hawkins & Harkin (1985) found that areas cleared of *Laminaria digitata* (moderately exposed) *Alaria esculenta* became the dominant canopy algae within 9 months (October - June). *Corallina officinalis* is capable of colonizing new substratum rapidly. In experimental plots 15 percent cover of fronds returned within 3 months (Littler & Kauker, 1985) and Brown & Taylor (1999) noted that the articulated coralline algal turf community on a New Zealand shore returned to normal levels within 3 months of trampling events, although they suggested that a return to its previous cover may take longer. Therefore general resilience of IR.HIR.KFaR.AlaAnCrSp & IR.HIR.KFaR.Ala plus associated sub-biotopes has been assessed as **High**.

The resilience and the ability to recover from human induced pressures is a combination of the environmental conditions of the site, the frequency (repeated disturbances versus a one-off event) and the intensity of the disturbance. Recovery of impacted populations will always be mediated by stochastic events and processes acting over different scales including, but not limited to, local habitat conditions, further impacts and processes such as larval supply and recruitment between populations. Full recovery is defined as the return to the state of the habitat that existed prior to impact. This does not necessarily

mean that every component species has returned to its prior condition, abundance or extent but that the relevant functional components are present and the habitat is structurally and functionally recognizable as the initial habitat of interest. It should be noted that the recovery rates are only indicative of the recovery potential.



Hydrological Pressures

| | Resistance | Resilience | Sensitivity |
|------------------------------|----------------------------------|--------------------------------|-----------------------------------|
| Temperature increase (local) | None Q: Medium A: High C: Low | High Q: High A: Low C: High | Medium Q: Medium A: Low C: Low |

Alaria esculenta is a northern/boreal species that has been recorded from Brittany, France to Northern Norway (Birkett *et al.*, 1998). Sea temperature regulates metabolism and reproduction and defines the regional distribution of *Alaria esculenta* (Fredersdorf *et al.*, 2009). The southern limit of *Alaria esculenta* has been defined at the 20°C isotherm (Munda & Lüning, 1977; Fredersdorf *et al.*, 2009), however, it is common north of the 16°C isotherm (Munda & Lüning, 1977). As a result of this upper temperature threshold, *Alaria esculenta* is largely absent from the southern North Sea and English channel where summer temperatures can exceed 16°C.

Munda & Lüning (1977) observed temperatures of 16-17°C sustained over 2 weeks in Helgoland, Germany, were lethal to resident *Alaria esculenta*. Experimental observations showed that acute exposure to $\geq 21^\circ\text{C}$ is lethal to *Alaria esculenta* causing bleaching and disintegration (Sundene, 1962; Fredersdorf *et al.*, 2009). At its northern range edge (Svalbard) it is a prominent macroalga on sublittoral fringe bedrock. At these latitudes, average summer temperature can reach 5°C, with an average annual sea temperature of 3°C (1980-2014, Beszczynska-Möller & Dye, 2013). Experimental observations conducted by Fredersdorf *et al.*, (2009) found the optimal temperature for sporophyte photosynthesis was within the range of 13-17°C, however, the optimal temperatures for *Alaria esculenta* germination is 2-12°C (Fredersdorf *et al.*, 2009).

Alaria esculenta has an approximate mid-range within southern Norway (60 deg to 65 deg North) (Birket *et al.*, 1998), and as such IR.HIR.KFaR.Ala and IR.HIR.KFaR.AlaAnCrSp (plus associated sub-biotopes) have a southerly distribution when considering the geographic distribution of *Alaria esculenta*. Throughout the UK northern to southern Sea Surface Temperature (SST) ranges from 8-16°C in summer and 6-13°C in winter (Beszczynska-Möller & Dye, 2013). The available evidence suggests that the effects of an increase in temperature would be seasonally variable, with higher impacts during periods of spore release (Nov-march) and germination. A 5°C increase in temperature for one month may cause high mortality, limit photosynthetic ability plus germination rates. A 2°C increase in temperature for one year may limit germination; however sporophyte photosynthetic ability may not be dramatically affected. Temperature increases of 2/5°C at the southern extreme of *Alaria esculenta*' range (Brittany, France) is likely to cause high mortality.

Corallina officinalis may tolerate between minus 4 to 28°C (Lüning, 1990). Abrupt temperature changes (10°C in California, Seapy & Littler 1984; 4.8 to 8.5°C, Hawkins & Hartnoll, 1985) resulted in dramatic declines. However, in both cases recovery was

rapid, suggesting that the crustose bases survived. Therefore, both *Alaria esculenta* and *Corallina officinalis* are probably intolerant of acute short-term temperature change of 5°C for a month. Long-term change of 2°C may reduce the southern limit of the population of *Alaria esculenta*.

Sensitivity assessment. Resistance to the pressure is considered 'None', and resilience 'High'. The sensitivity of this biotope to an increase in temperature has been assessed as 'Medium'. This sensitivity assessment takes into account a temperature increase of 5°C for one month. The effects of a 2°C increase in temperature for one year is likely to have less of an impact. In the later scenario, resistance would be assessed as "Medium", and resilience "High". Sensitivity would be assessed as "Low".

Temperature decrease (local)

High

Q: High A: Medium C: Medium

High

Q: High A: Low C: High

Not sensitive

Q: High A: Low C: Medium

Alaria esculenta is a northern/boreal species that has been recorded from Brittany, France to Northern Norway (Birkett *et al.*, 1998). Sea temperature has been cited as an influential abiotic stressor; responsible for regulating metabolism and reproduction, plus defining the regional distribution of *Alaria esculenta* (Fredersdorf *et al.*, 2009). At *Alaria*'s northern range edge (Svalbard) it is a prominent macro-algae on sub-littoral fringe bedrock. At these latitudes, average summer temperature can reach 5°C, and average annual sea temperature 3°C (1980-2014, Beszczynska-Möller & Dye, 2013). Experimental observations conducted by Fredersdorf *et al.*, (2009) found the optimal temperature for sporophyte photosynthesis was within the range of 13-17°C, however, the optimal temperatures for *Alaria esculenta* germination is 2-12°C (Fredersdorf *et al.*, 2009).

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

Salinity increase (local)

Medium

Q: Medium A: High C: High

High

Q: High A: Low C: High

Low

Q: Medium A: Low C: High

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.

Karsten (2007) tested the photosynthetic ability of *Alaria esculenta* under acute 2 & 5 day exposure to salinity treatments ranging from 5-60 psu. A control experiment was also carried at 34 PSU. Between 10-50 psu *Alaria esculenta* showed high photosynthetic ability at 83-94% of the control. Hypersaline treatments with 55-60 psu led to a 30% reduction in photosynthetic ability, ~70% of the control level. At 5 psu *Alaria esculenta* showed a low photosynthetic ability at 15.8% of the control. After 5 days at 5 psu all *Alaria esculenta* specimens were bleached and none survived. Karsten (2007) suggested that *Alaria esculenta* photosynthetic ability is highly affected by acute exposure to hyposaline conditions (<10 psu). The effect of long-term salinity changes (>5 days) or the effect of salinity >60 psu on *Alaria esculenta*' photosynthetic ability was not tested. The experiment was conducted in the Arctic, and the authors suggest that at extremely low water temperatures (1-5°C) macro-algal acclimation to rapid salinity changes could be slower than at temperate latitudes. It is therefore possible that *Alaria esculenta* maybe be able to acclimate to salinity changes more effectively and quicker in UK waters, however evidence for this is limited.

Corallina officinalis is restricted to full salinity waters in the Baltic and grows maximally between 33 and 38 psu in Texan lagoons (Kinne 1971). This biotope is likely to be exposed to short-term freshwater runoff at low tide but is likely to be intolerant of long-term changes in salinity, which are likely to depress its upper limit and reduce the extent of the population.

Sensitivity assessment. IR.HIR.KFaR.AlaAnCrSp & IR.HIR.KFaR.Ala plus associated sub-biotopes have been recorded exclusively in full salinity (30-40‰) (Connor *et al.*, 2004). Karsten (2007) suggests that at salinities ranging from 10-50 psu *Alaria esculenta* photosynthetic ability was high. At salinities >50 psu, photosynthetic ability was reduced by 30% but no mortality of the specimens was recorded. Resistance to the pressure is considered 'Medium', as other characterizing species (e.g. sponges, ascidians) are likely to be more sensitive to hypersaline conditions and resilience 'High'. The sensitivity of this biotope to an increase in salinity has been assessed as 'Low'.

| | | | |
|---------------------------|---------------------------|------------------------|--------------------------|
| Salinity decrease (local) | Medium | High | Low |
| | Q: Medium A: High C: High | Q: High A: Low C: High | Q: Medium A: Low C: High |

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.

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Sensitivity assessment. IR.HIR.KFaR.AlaAnCrSp & IR.HIR.KFaR.Ala plus associated sub-biotopes have been recorded exclusively in full salinity (30-40‰) (Connor *et al.*, 2004). Karsten (2007) suggests that at salinities ranging from 10-50 PSU *Alaria esculenta* photosynthetic ability was high. At 5 PSU *Alaria esculenta* showed a dramatic decline in photosynthetic ability and after 5 days specimens bleached and did not survive. Sundene (1962) also noted that *Alaria esculenta* sporophytes grew poorly below 25 PSU. A decrease of 1 MNCR salinity scale to "Reduced Salinity" (18-30‰) may reduce growth rates, however not cause high mortality of *Alaria esculenta*. Resistance to the pressure is therefore considered 'Medium', as other characterizing species (e.g. sponges, ascidians) are likely to be more sensitive to hyposaline conditions, and resilience 'High'. The sensitivity of this biotope to an increase in salinity has been assessed as 'Low'.

Water flow (tidal current) changes (local)

Medium

Q: Low A: NR C: NR

High

Q: High A: Low C: High

Low

Q: Low A: NR C: NR

Alaria esculenta dominates the sublittoral fringe in areas exposed to severe wave action or where water surges along the sides of gullies/steep bedrock faces (Lewis, 1964; Connor *et al.*, 2004). The high wave exposure that defines IR.HIR.KFaR.AlaAnCrSp & IR.HIR.KFaR.Ala plus associated sub-biotopes damages other laminarians, and generally excludes them. In less wave exposed locations *Alaria esculenta* is out-competed by other Laminarians, e.g. *Laminaria digitata* and *Laminaria hyperborea* (Connor *et al.*, 2004). IR.HIR.KFaR.AlaAnCrSp and IR.HIR.KFaR.Ala plus associated sub-biotopes are recorded within moderately strong (0.5-1.5 m/sec)-weak (<0.5m/sec) tidal streams, but have been recorded in very strong (>3 m/sec) tidal streams. Therefore, while elevated tidal flows (>3 m/sec) may increase *Alaria esculenta* dislodgment (Birket *et al.*, 1998).

Increased tidal flow may remove fronds of *Corallina officinalis* however calcification is thought to be an adaptation to mechanical damage (Littler & Kauker 1984). Increases in water flow rate may facilitate the colonization of filter feeding organisms within the understory and IR.HIR.KFaR.Ala.Myt may dominate over IR.HIR.KFaR.Ala.Ldig. Decreases in water flow are likely to have the opposite effect (Connor *et al.* 2004). Changes in the water flow regimes under kelp canopies can modify larval supply and

settlement (Eckman, 1983), and affect the growth and survival of *Mytilus edulis* (Eckman & Duggins, 1991). *Mytilus edulis* settlement has been found significantly higher in close proximity to *Alaria esculenta* and is thought to increase beneath the canopy (Bégin *et al.*, 2004). Therefore any loss of *Alaria esculenta*, as a result of changes to local water movements, may affect *Mytilus edulis* recruitment.

Sensitivity assessment. IR.HIR.KFaR.AlaAnCrSp & IR.HIR.KFaR.Ala plus associated sub-biotopes are found in a wide range of tidal flows but exclusively in wave disturbed areas, which generally exclude other laminarians. Changes in tidal flow are not likely to independently affect the dominance of *Alaria esculenta*, however, may affect the understory community. Nevertheless, wave exposure is the dominant source of water movement in these biotope, and a change in water flow of 0.1-0.2 m/s is unlikely to be significant. Therefore, resistance has been assessed as '**High**' and resilience '**High**'. Sensitivity has been assessed as '**Not Sensitive**' at the benchmark level.

Emergence regime changes

Low

Q: Low A: NR C: NR

High

Q: High A: Low C: High

Low

Q: Low A: NR C: NR

An increase in emergence will result in an increased risk of desiccation. Increased immersion may allow IR.HIR.KFaR.Ala biotopes to extend higher up the shore. However, *Alaria esculenta* forest will come under increased competition from *Laminaria hyperborea* in the shallow infralittoral. In this scenario IR.HIR.KFaR.Ala biotope distribution may shift on the shore, however, biotope structure will remain.

Alaria esculenta may extend into the lower eulittoral in extremely wave exposed conditions. However, these marginal populations have a reduced age range in comparison to subtidal populations due to desiccation increasing mortality of *Alaria esculenta* at low tide. An increase in desiccation is likely to remove *Alaria esculenta*. The resultant loss of canopy would expose *Corallina officinalis* turf and macrofaunal crust to desiccation and/or damage by high light intensity (bleaching). Hawkins & Harkin (1985) noted that encrusting corallines and *Corallina officinalis* often die when their protective algal canopy is removed. Severe damage was noted in *Corallina officinalis* as a result of unusually hot and sunny weather in the UK summer 1983 (Hawkins & Hartnoll, 1985). *Laminaria digitata* is likely to be intolerant of desiccation and destruction of its meristem (base of the blade), caused by increased wave action at low tide, will kill the sporophyte. Therefore, both IR.HIR.KFaR.Ala.Myt and IR.HIR.KFaR.Ala.Ldig are likely to be highly intolerant of increases in desiccation and the upper limit of the population would be depressed. Desiccation is unlikely to be relevant in IR.HIR.KFaR.AlaAnCrSp due to its depth (15-35m BCD) (Connor *et al.*, 2004).

Sensitivity assessment. Resistance to this pressure is considered '**Low**', and resilience '**High**'. The sensitivity of this biotope to a change in emergence is considered as '**Low**'.

Wave exposure changes (local)

None

Q: High A: High C: High

High

Q: High A: Low C: High

Medium

Q: High A: Low C: High

Alaria esculenta dominates the sublittoral fringe in areas exposed to severe wave

action or where water surges along the sides of gullies (Lewis, 1964). A decrease in local wave height will increase spatial competition from other laminarians (Connor *et al.*, 2004). Increased wave exposure may remove fronds of *Corallina officinalis* however calcification is thought to an adaptation to mechanical damage (Little & Kauker 1984) and the fronds grow as a compact (short) turf in wave exposed conditions.

IR.HIR.KFaR.AlaAnCrSp occurs at one site, Rockall, Scotland where extreme oceanic swell excludes *Laminaria hyperborea* in the infralittoral from 14-35 m.

IR.HIR.KFaR.Ala.Myt occurs predominantly on sub-littoral fringe bedrock in very exposed to exposed wave exposure. Extremely wave exposed variants of IR.HIR.KFaR.Ala.Myt can extend to 15 m BCD where *Alaria esculenta* replaces *Laminaria hyperborea* as the assemblage dominant, and *Mytilus edulis* is a common understory species in the sublittoral fringe variant (Bégin *et al.*, 2004, Connor *et al.*, 2004) but as depth increases *Tubularia spp.* becomes more abundant.

IR.HIR.KFaR.Ala.Ldig occurs predominately at exposed-moderately wave exposed sites, where *Laminaria digitata* can spatially compete with *Alaria esculenta* (Connor *et al.*, 2004).

Sensitivity assessment. The abundance of *Alaria esculenta* is highly affected by the degree of wave exposure at a site. Within IR.HIR.KFaR.Ala, increasing wave exposure may favour IR.HIR.KFaR.Ala.Myt over IR.HIR.KFaR.Ala.Ldig (Connor *et al.* 2004). Further increases in wave exposure may cause damage to *Laminaria hyperborea*, allowing *Alaria esculenta* to dominate the infralittoral. Kelp clearance experiments have shown that at moderate or lower wave exposure sites *Laminaria digitata* can out-compete *Alaria esculenta* so that a decrease in wave exposure is likely to result in loss of the *Alaria* dominated biotopes. *Alaria* dominated biotopes are therefore, sensitive to any activity or event that reduces incident wave energy. However, a change of 3-5% in significant wave height (the benchmark) is unlikely to be significant in the wave exposed conditions favoured by these biotopes. Therefore, resistance is recorded as '**High**', with a '**High**' resilience, resulting is an assessment of '**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.

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

references therein).

Mercury (organic > inorganic) is highly toxic to macrophytes (Bryan 1984; Cole *et al.* 1999). Mercury and copper were lethal at 0.05 mg/l and 0.1 mg/l respectively and toxic at 0.05 mg/l and 0.01 mg/l respectively in *Laminaria hyperborea*. Zinc and Cadmium were lethal at 5 mg/l and 10 mg/l respectively. The presence of alginates in kelp tissue is thought to sequester heavy metals in a biologically unavailable form. It is likely that laminarians such as *Alaria esculenta* are relatively tolerant of heavy metals except at high concentrations at high levels. Little information on heavy metal tolerance of corallines was found.

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 mucilaginous coating on kelp fronds is thought to protect them from coatings of oil. Hydrocarbons in solution reduce photosynthesis and may be algicidal. Reduction in photosynthesis is dependent on the type of oil, its concentration and length of exposure, oil-water mixture and irradiance in experimental trials (Lobban & Harrison, 1994). Subtidal populations are only exposed to oil emulsions or oil adsorbed particles. Kelps are relatively insensitive to dispersants (Birkett *et al.* 1998) e.g. *Laminaria digitata* exposed to diesel oil at 0.130 mg/l reduced growth by 50% in a 2 year experiment. No growth inhibition was noted at 0.03 mg/l and the plants recovered completely in oil free conditions. *Coralliina officinalis*, however, exhibited dramatic bleaching after the *Sea Empress* oil spill and died after the *Torrey Canyon* spill (Crump *et al.* 1999; Smith 1968). Encrusting corallines and *Coralliina officinalis* recovered from the *Sea Empress* spill quickly, bleaching only affecting the fronds or surface of crustose forms. Grazing gastropods, e.g. limpets are highly intolerant of oil spillage and if not killed are narcotized and washed offshore and/or consumed by predators. The lower littoral populations are likely to be most vulnerable to oil spill and sublittoral fringe would be particularly affected at low tide. Although *Alara esculenta* may not be affected severely, the articulated coralline turf may be lost but recover quickly although the red algae may be intolerant. Grazers such as limpets, barnacles and meiofaunal crustaceans may also be lost from the community.

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.

Cole *et al.* 1999 suggest that macrophytes are generally intolerant of herbicides such as atrazine, simazine, diuron and linuron e.g. atrazine was lethal to *Laminaria hyperborea* sporophytes at 1mg/l and suppressed growth at 0.01 mg/l (Hopkin & Kain, 1978). Smith (1968) noted that *Corallina officinalis* was killed in areas of heavy spraying after the *Torrey Canyon* oil spill and affected at 6 m depth in areas of high wave action. High water specimens were more affected than low water specimens, presumably because they are emmersed for longer and had more contact with oil and dispersants. Gastropods are known to be highly sensitive to endocrine disrupters

such as TBT. Crustaceans (e.g. amphipods, isopods, ostracods, copepods and barnacles) are also susceptible to endocrine disruption by synthetic chemicals. It is, therefore, likely that some taxa within IR.HIR.KFaR.AlaAnCrSp & IR.HIR.KFaR.Ala plus associated sub-biotopes, especially grazing invertebrates and meiofauna will be intolerant of synthetic chemical contamination.

| | | | |
|-----------------------------------|---|---|---|
| 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: High A: Medium C: High | High Q: High A: Medium C: High | Not sensitive Q: High A: Medium C: High |
|-----------------------|--|--|---|

Reduced oxygen concentrations have been shown to inhibit both photosynthesis and respiration in macroalgae (Kinne, 1977). Despite this, macroalgae are thought to buffer the environmental conditions of low oxygen, thereby acting as a refuge for organisms in oxygen depleted regions especially if the oxygen depletion is short-term (Frieder *et al.*, 2012). A rapid recovery from a state of low oxygen is expected if the conditions are transient, which is likely given the wave exposed distribution of defines IR.HIR.KFaR.AlaAnCrSp & IR.HIR.KFaR.Ala plus associated sub-biotopes. 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). Reduced oxygen levels are likely to inhibit photosynthesis and respiration but not cause a loss of the macroalgae population directly. However, small invertebrate epifauna may be lost, causing a reduction in species richness.

Sensitivity assessment. Due to the mixing experienced in strongly wave exposed environment, resistance has been assessed as “**High**” resilience as “**High**”. Sensitivity has been assessed as “**Not Sensitive**” at the pressure benchmark level.

| | | | |
|----------------------------|---|---|---|
| Nutrient enrichment | Not relevant (NR) Q: NR A: NR C: NR | Not relevant (NR) Q: NR A: NR C: NR | Not sensitive Q: NR A: NR C: NR |
|----------------------------|---|---|---|

Organic enrichment is associated with eutrophication, increased siltation and turbidity (Fletcher 1996). Eutrophication is associated with loss of perennial algae and replacement by mussels or opportunistic algae (Fletcher 1996). Johnston & Roberts (2009) conducted a meta-analysis that reviewed 216 papers to assess how a variety of contaminants (including sewage and nutrient loading) affected 6 marine habitats (including intertidal and subtidal reefs). A 30-50% reduction in species diversity and richness was identified from all habitats exposed to the contaminant types. Johnston & Roberts (2009) also highlighted that macroalgal communities are relative

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

Organic enrichment is associated with eutrophication, increased siltation and turbidity (Fletcher 1996). Eutrophication is associated with loss of perennial algae and replacement by mussels or opportunistic algae (Fletcher 1996). Johnston & Roberts (2009) conducted a meta-analysis that reviewed 216 papers to assess how a variety of contaminants (including sewage and nutrient loading) affected six marine habitats (including intertidal and subtidal reefs). A 30-50% reduction in species diversity and richness was identified from all habitats exposed to the contaminant types. Johnston & Roberts (2009) also highlighted that macroalgal communities are relatively tolerant to contamination, but that contaminated intertidal communities can have low diversity assemblages which are dominated by opportunistic and fast growing species (Johnston & Roberts, 2009 and references therein). Due to the high wave exposure that defines IR.HIR.KFaR.AlaAnCrSp & IR.HIR.KFaR.Ala plus associated sub-biotopes, it is likely that additional organic input to the system may be dispersed out of the biotope's local vicinity (Johnston & Roberts, 2009). Increased nutrients may favour *Mytilus edulis* in IR.HIR.KFaR.Ala.Myt which may increase in cover and abundance. *Corallina officinalis* is also tolerant of polluted waters (Kindig & Littler, 1980).

Sensitivity assessment. Resistance has been assessed as “**Medium**”, (to represent potential changes in species diversity), resilience as “**High**”. Sensitivity has been assessed as “**Low**”.

A 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.

| | | | |
|---|--|--|--|
| | Resistance | Resilience | Sensitivity |
| 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 *Alaria esculenta* would not 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 hard rock or artificial substrata to sedimentary or soft rock substrata is assessed as ‘**High**’.

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

Not Relevant to hard rock biotopes.

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

Not Relevant to hard rock biotopes.

| | | | |
|---|--------------------|------------------------|--------------------|
| Abrasion/disturbance of the surface of the substratum or seabed | Medium | High | Low |
| | Q: Low A: NR C: NR | Q: High A: Low C: High | Q: Low A: NR C: NR |

The sublittoral fringe is unlikely to be significantly impacted by trampling due to its position of the lower shore but may be prone to abrasion from moorings or low tide landings. Given its resilience to wave action *Alaria esculenta* is unlikely to be significantly damaged by abrasion although the understory coralline turf may suffer some damage. The coralline turf meiofauna will probably be lost as a result of trampling. Moderate trampling on articulated coralline algal turf in the New Zealand intertidal (Brown & Taylor 1999; Schiel & Taylor 1999) resulted in reduced turf height, declines in turf densities, and loss of crustose bases in some case probably due to loss of the canopy algae and resultant desiccation. Calcification is thought to an adaptation to grazing and sediment scour (Littler & Kauker 1984).

If exposed to moorings, groundings, or passing fishing gear, the resultant abrasion may result in the physical removal of a proportion of the *Alaria esculenta* canopy. Depending on the scale of the impact, although no evidence of this impact was found. However, *Alaria esculenta* has been shown to be an opportunistic colonizing species, capable of rapid recovery (see resilience section).

Sensitivity assessment. Resistance has been assessed as 'Medium', resilience as 'High'. Sensitivity has been assessed as 'Low'.

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

Not Relevant to hard rock biotopes.

| | | | |
|---|--------------------|------------------------|----------------------|
| Changes in suspended solids (water clarity) | Medium | High | Low |
| | Q: Low A: NR C: NR | Q: High A: Low C: High | Q: Low A: Low C: Low |

Suspended Particle Matter (SPM) concentration has a linear relationship with sub surface light attenuation (Kd) (Devlin *et al.*, 2008). Light penetration influences the maximum depth at which kelp species can grow and it has been reported that laminarians grow at depths at which the light levels are reduced to 1 percent of incident light at the surface. Maximal depth distribution of laminarians, therefore,

varies from 100 m in the Mediterranean to only 6-7 m in the silt-laden German Bight. In European Atlantic waters, the depth limit is typically 35 m.

Alaria esculenta is not found in areas of siltation and sediment scour (Birkett *et al.* 1998). Increased siltation and sediment scour inhibits photosynthesis and algal growth, interfere with spore or larval recruitment plus smother germlings and gametophytes (Fletcher 1996). However, the high degree of wave exposure that typically defines IR.HIR.KFaR.AlaAnCrSp & IR.HIR.KFaR.Ala plus associated sub-biotopes is likely to clear suspended sediments relatively quickly. If low water clarity is persistent and wave exposure decreased then low energy silted kelp biotopes (IR.LIR.K) may proliferate. Once siltation returns to its pre-effect level the biotope is likely to recover its canopy within a year and the rest of the community in no more than five years. Increased siltation will also increase turbidity. Increased sediment may benefit *Mytilus edulis* and its abundance may increase in IR.HIR.KFaR.Ala.Myt although large individuals are likely to be removed by wave action.

Increased turbidity is likely to reduce the depth to which *Alaria esculenta* can grow. However, an increase of one level in WFD water clarity scale for a period of one year is unlikely to affect the population since *Alaria esculenta*'s lower limit, is generally determined by competition from other Laminarians rather than light penetration.

Sensitivity assessment. Resistance has been assessed as **Medium**, Resilience as **High**. Sensitivity has been assessed as **Low**.

Smothering and siltation rate changes (light)

High

Q: Medium A: Low C: High

High

Q: High A: Low C: High

Not sensitive

Q: Medium A: Low C: Medium

Due to their size juvenile sporophytes, germlings, gametophytes and spores are likely to be inundated by deposition of 5cm during a discrete event but the high wave exposure that defines the distribution of IR.HIR.KFaR.AlaAnCrSp & IR.HIR.KFaR.Ala (plus associated sub-biotopes deposited sediments) are likely to be removed rapidly and any effects of inundation are likely to be temporary.

Sensitivity assessment. Resistance has been assessed as '**High**', Resilience as '**High**'. Sensitivity has been assessed as '**Not Sensitive**'.

Smothering and siltation rate changes (heavy)

High

Q: Medium A: Low C: Medium

High

Q: High A: Low C: High

Not sensitive

Q: Medium A: Low C: Medium

Due to their size juvenile sporophytes, germlings, gametophytes and spores are likely to be inundated by deposition of 30cm during a discrete event but the high wave exposure that defines the distribution of IR.HIR.KFaR.AlaAnCrSp & IR.HIR.KFaR.Ala (plus associated sub-biotopes deposited sediments) are likely to be removed rapidly and any effects of inundation are likely to be temporary.

Sensitivity assessment. Resistance has been assessed as '**High**', Resilience as '**High**'. Sensitivity has been assessed as '**Not Sensitive**'.

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

Not assessed. No evidence to suggest that litter would affect IR.HIR.KFaR.AlaAnCrSp & IR.HIR.KFaR.Ala plus associated sub-biotopes was found.

| | | | |
|--------------------------------|--------------------------|--------------------------|--------------------------|
| Electromagnetic changes | 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 |

No evidence

| | | | |
|---------------------------------|--------------------------|--------------------------|--------------------------|
| Underwater noise changes | Not relevant (NR) | Not relevant (NR) | Not relevant (NR) |
| | Q: NR A: NR C: NR | Q: NR A: NR C: NR | Q: NR A: NR C: NR |

Not relevant

| | | | |
|---|--------------------|-------------------------|--------------------|
| Introduction of light or shading | Low | High | Low |
| | Q: Low A: NR C: NR | Q: High A: High C: High | Q: Low A: NR C: NR |

There was no evidence to suggest that anthropogenic light sources would affect IR.HIR.KFaR.AlaAnCrSp & IR.HIR.KFaR.Ala plus associated sub-biotopes. Shading (e.g. by construction of a pontoon, pier etc) could adversely affect the biotope in areas where the water clarity is also low, and tip the balance to shade tolerant species, resulting in the loss of the biotope directly within the shaded area, or a reduction in laminarian abundance from forest to park type biotopes.

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

| | | | |
|------------------------------------|--------------------------|--------------------------|--------------------------|
| Barrier to species movement | Not relevant (NR) | Not relevant (NR) | Not relevant (NR) |
| | Q: NR A: NR C: NR | Q: NR A: NR C: 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 benchmarks, 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) | Not relevant (NR) | Not relevant (NR) |
| | Q: NR A: NR C: NR | Q: NR A: NR C: NR | Q: NR A: NR C: NR |

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

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

| | | | |
|---|---------------------------------|-----------------------------------|--|
| Introduction or spread of invasive non-indigenous species | High Q: High A: High C: High | High Q: High A: Medium C: High | Not sensitive Q: High A: Medium C: High |
|---|---------------------------------|-----------------------------------|--|

The Japanese kelp *Undaria pinnatifida* (wakame) has recently spread to the south coast of England from Brittany where it was introduced for aquaculture. It may spread in ballast water of commercial or recreational boats and shipping. Field studies within New Zealand found that the physical structure of coralline turfing algae substantially aided the establishment of *Undaria pinnatifida* in the intertidal. The physical structure of coralline turfing algae (e.g. *Corallina officinalis*) retains moisture, provide a physical barrier to grazers, and create a physically complex habitat on which algal spores can settle (Thompson & Schiel, 2012). Once established *Undaria pinnatifida* has been associated with declines in native kelp abundance (e.g. *Laminaria hyperborea*, Heiser *et al.*, 2014). In the UK *Undaria pinnatifida* has to date only been recorded from predominantly sheltered locations e.g. harbours (Thompson & Schiel, 2012). The high wave exposure which defines IR.HIR.KFaR.AlaAnCrSp & IR.HIR.KFaR.Ala plus associated sub-biotopes may inhibit the establishment of *Undaria pinnatifida* However colonization of *Undaria pinnatifida* within UK habitats needs further study (Birkett *et al.* 1998, Heiser *et al.*, 2014).

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

| | | | |
|-------------------------------------|------------------------------------|-----------------------------------|---|
| Introduction of microbial pathogens | High Q: Medium A: Medium C: Low | High Q: High A: Medium C: High | Not sensitive Q: Medium A: Medium C: Low |
|-------------------------------------|------------------------------------|-----------------------------------|---|

Streblonema sp. is associated with spot disease in kelps and has been found growing on *Alaria esculenta* (Lein *et al.* 1991) but no incidence of *Alaria esculenta* spot disease was found. *Corallina officinalis* may host several epiphytes of which *Titanoderma corallinae* is thought to cause tissue damage. Hyperplasia or gall growths are often seen as dark spots on *Laminaria digitata* and have been associated with endophytic brown filamentous algae. There is no evidence in the literature that infection by microbial pathogens results in the mass death of kelp populations and the kelp themselves are known to regulate bacterial infections through iodine metabolism (Cosse *et al.*, 2009).

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

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

Alaria esculenta has recently received commercial interest as a consumable product called “Sea Vegetables” or “Atlantic Wakame Kelp”. However no studies examining the effect of commercial extraction of *Alaria esculenta* biotopes were found. Removal of the algal canopy would expose the understory fauna and flora to increased desiccation. Experimental macroalgal canopy removal experiments conducted in the Isle of Man (Hawkings & Harkin, 1985) found that following the removal of the macroalgal canopy the understory encrusting red algae became bleached and died within a week. *Mytilus edulis* settlement has also been found significantly higher in close proximity to *Alaria esculenta* and is thought to increase beneath *Alaria esculenta* canopies (Bégin *et al.*, 2004). Therefore, any loss of *Alaria esculenta*, as a result of commercial extraction, may dramatically affect the understory community.

Traditionally *Laminaria digitata* was added to agricultural lands as fertilizers; now *Laminaria* species are used in a range of different products, with its alginates used in the cosmetic, pharmaceutical and agri-food industries (Kervarec *et al.*, 1999; McHugh, 2003). *Laminaria digitata* is harvested with a ‘Scoubidou’ (a curved iron hook which is mechanically operated) in France. 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). The loss of *Laminaria digitata* would represent as significant change to IR.HIR.KFaR.Ala.Ldig.

Corallina officinalis is collected for medical purposes; the fronds are dried and converted to hydroxyapatite and used as bone forming material (Ewers *et al.* 1987). It is also sold as a powder for use in the cosmetic industry. Moderate trampling on articulated coralline algal turf in the New Zealand intertidal (Brown & Taylor 1999; Schiel & Taylor 1999) resulted in reduced turf height, declines in turf densities, and loss of crustose bases in some case probably due to loss of the canopy algae and resultant desiccation. Calcification is thought to be an adaptation to grazing and sediment scour (Littler & Kauker 1984). *Corallina officinalis* produces spores over a protracted period and can colonize artificial substratum within one week in the intertidal (Harkin & Lindbergh 1977; Littler & Kauker 1984). The crustose base enables *Corallina officinalis* to survive the loss of fronds.

Sensitivity assessment. There is little evidence for the effects of commercial harvesting of *Alaria esculenta*. If it is assumed that all canopy forming kelp are removed then resistance would be assessed as ‘None’, resilience would be assessed as ‘Medium’. Sensitivity has been assessed as ‘Medium’. Within IR.HIR.KFaR.AlaAnCrSp and IR.HIR.KFaR.Ala.Myt, monospecific canopies of *Alaria esculenta* are expected to recover quicker than mixed canopies of *Laminaria digitata* (as in IR.HIR.KFaR.Ala.Ldig) Sensitivity of the latter would be assessed as follows; resistance ‘None’, resilience as ‘High’, Sensitivity as ‘Medium’.

Removal of non-target species

None

Q: High A: High C: High

Medium

Q: High A: High C: High

Medium

Q: High A: High C: High

Incidental/accidental removal of *Alaria esculenta* is likely to cause similar effects to that of direct harvesting; hence, the same evidence has been used for both pressure assessments.

Alaria esculenta has recently received commercial interest as a consumable product

called “Sea Vegetables” or “Atlantic Wakame Kelp”. However, no studies examining the effect of commercial extraction of *Alaria esculenta* biotopes were found. Removal of the algal canopy would expose the understory fauna and flora to increased desiccation. Experimental macroalgal canopy removal experiments conducted in the Isle of Man (Hawkings & Harkin, 1985) found that following the removal of the macroalgal canopy the understory encrusting red algae became bleached and died within a week. *Mytilus edulis* settlement has also been found significantly higher in close proximity to *Alaria esculenta* and is thought to increase beneath *Alaria esculenta* canopies (Bégin *et al.*, 2004). Therefore, any loss of *Alaria esculenta*, as a result of commercial extraction, may dramatically affect the understory community.

Traditionally *Laminaria digitata* was added to agricultural lands as fertilizers; now *Laminaria* species are used in a range of different products, with its alginates used in the cosmetic, pharmaceutical and agri-food industries (Kervarec *et al.*, 1999; McHugh, 2003). *Laminaria digitata* is harvested with a ‘Scoubidou’ (a curved iron hook which is mechanically operated) in France. 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). The loss of *Laminaria digitata* would represent as a significant change to IR.HIR.KFaR.Ala.Ldig.

Corallina officinalis is collected for medical purposes; the fronds are dried and converted to hydroxyapatite and used as bone forming material (Ewers *et al.* 1987). It is also sold as a powder for use in the cosmetic industry. Moderate trampling on articulated coralline algal turf in the New Zealand intertidal (Brown & Taylor 1999; Schiel & Taylor 1999) resulted in reduced turf height, declines in turf densities, and loss of crustose bases in some case probably due to loss of the canopy algae and resultant desiccation. Calcification is thought to be an adaptation to grazing and sediment scour (Littler & Kauker 1984). *Corallina officinalis* produces spores over a protracted period and can colonize artificial substratum within one week in the intertidal (Harkin & Lindbergh 1977; Littler & Kauker 1984). The crustose base enables *Corallina officinalis* to survive loss of fronds.

Sensitivity assessment. There is little evidence for the effects of commercial harvesting of *Alaria esculenta*. If it is assumed that all canopy-forming kelp are removed then resistance would be assessed as ‘None’, resilience would be assessed as ‘Medium’. Sensitivity has been assessed as ‘Medium’. Within IR.HIR.KFaR.AlaAnCrSp and IR.HIR.KFaR.Ala.Myt, monospecific canopies of *Alaria esculenta* are expected to recover quicker than mixed canopies of *Laminaria digitata* (as in IR.HIR.KFaR.Ala.Ldig) Sensitivity of the latter would be assessed as follows; resistance ‘None’, resilience as ‘High’, Sensitivity as ‘Medium’.

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