Ascophyllum nodosum ecad *mackayi* beds on extremely sheltered mid eulittoral mixed substrata

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

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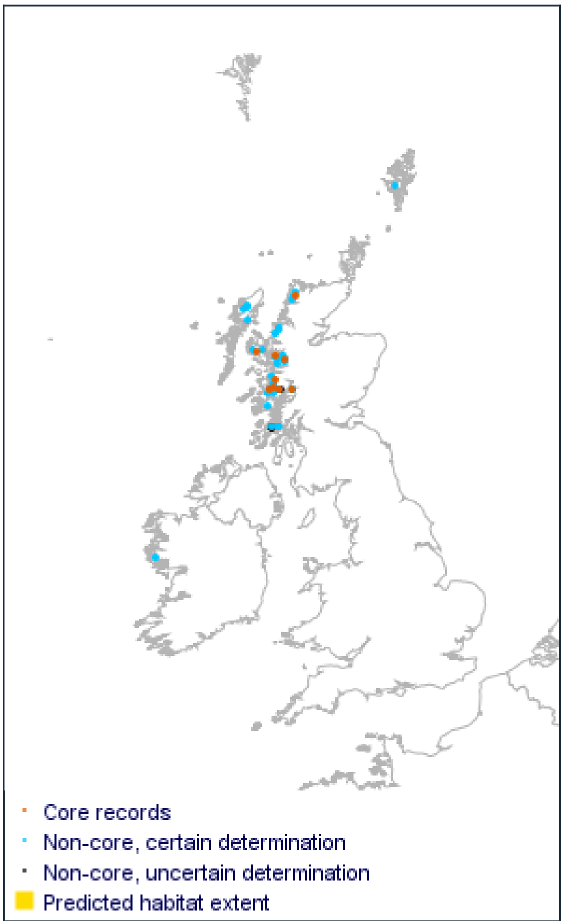
A dense mat of ***Ascophyllum nodosum mackaii.***
Photographer: Sue Scott



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

Researched by Frances Perry & Jacqueline Hill **Refereed by** This information is not refereed.

Summary

UK and Ireland classification

EUNIS 2008	A1.325	*Ascophyllum nodosum* ecad. *mackaii* beds on extremely sheltered mid eulittoral mixed substrata
JNCC 2015	LR.LLR.FVS.Ascmac	*Ascophyllum nodosum* ecad *mackayi* beds on extremely sheltered mid eulittoral mixed substrata
JNCC 2004	LR.LLR.FVS.Ascmac	*Ascophyllum nodosum* ecad mackaii beds on extremely sheltered mid eulittoral mixed substrata
1997 Biotope	LR.SLR.FX.AscX.mac	*Ascophyllum nodosum* ecad. mackaii beds on extremely sheltered mid eulittoral mixed substrata

Description

Extremely sheltered mid shore mixed substrata, usually subject to variable salinity due to freshwater runoff, may support beds of the free-living form of the wrack *Ascophyllum nodosum* ecad *mackayi*. Cobbles and other hard substrata are often characterized by the normal form of *Ascophyllum nodosum* and other fucoids such as *Fucus serratus* and *Fucus vesiculosus* and the red seaweed *Polysiphonia lanosa* growing as an epiphyte. The loose mats of *Ascophyllum nodosum* ecad *mackayi* provide a cryptic and humid habitat for mobile species such as gammarids, the shore crab *Carcinus maenas*, littorinid molluscs (especially *Littorina littorea*) and eels *Anguilla anguilla*. *Semibalanus balanoides* and *Mytilus edulis* are commonly attached to pebbles and cobbles on the sediment, while the infauna may contain *Arenicola marina*, *Lanice conchilega* and other polychaetes. *Ascophyllum nodosum* ecad *mackayi* develops initially from broken fragments of *Ascophyllum nodosum* and can in sheltered conditions grow in unattached, often bladderless, wig-shaped masses in the mid to upper tide zone. (Information from Connor *et al.*, 2004; JNCC, 2105).

Depth range

Upper shore, Mid shore, Lower shore

Additional information

Note: "Ecad" has no official status in International Code of Botanical Nomenclature, but the terminology has been applied to the free-living form of *Ascophyllum nodosum* since the beginning of the 19th century. The term was first employed by Clements (1905) to denote a form which results from adaptation or a change in morphology due to a new habitat - phenotypic variation (Connor *et al.*, 2004).

Listed By

- none -

Further information sources

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Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

This biotope is characterized by the unattached growth form of *Ascophyllum nodosum* that develops in response to the very specific environmental conditions found within this biotope. This specific environmental form (ecad) is created when fragments of *Ascophyllum nodosum* become washed into sheltered shores where conditions allow them to continue to branch independently of the original fragment (Chock & Mathieson, 1976). These fragments create large spherical masses (*Ascophyllum nodosum* ecad *mackayi*), and in optimum conditions can create extensive rafts made up of numerous spherical masses. These rafts of weed provide habitat for a range of mid-shore organisms that would otherwise not be able to survive in the sedimentary conditions that are characteristic of the very sheltered sea loch conditions. The environmental conditions within this biotope have to be very stable, with very little wave action or water flow. Variable salinity is characteristic of this biotope and is most often created by freshwater runoff, from the hills around the head of the sea lochs where this biotope is found.

This biotope forms in areas where the sediment is comprised of pebbles and cobbles on mud and sand. The normal form of *Ascophyllum nodosum* can be found along with *Fucus vesiculosus* on the larger stones or small boulders. *Polysiphonia lanosa* grows epiphytically on both of these macroalgae species. The barnacle *Semibalanus balanoides* and the blue mussel *Mytilus edulis* are found on the pebbles and cobbles. In the finer sediments, the infauna is dominated by *Arenicola marina* and *Lanice conchilega*. An abundance of mobile fauna, including gammarids, *Carcinus maenas*, and grazing littorinids such as *Littorina littorea*, *Littorina obtusata*, and *Littorina saxatilis* occur within the fronds of *Ascophyllum nodosum* ecad *mackayi*. Fish such as young common eels *Anguilla anguilla* and viviparous blennies *Zoarces viviparous* may also shelter in the weed.

Ascophyllum nodosum ecad *mackayi* is the key structuring species of this biotope, whose loss would result in loss of the biotope. This species acts as an ecosystem engineer and the frond canopy created by this species modifies habitat conditions. The canopy created by the raft of weed provides protection to a number of mobile species in addition to providing a substratum for epifauna and being the primary food resource for grazers. This can facilitate the existence and survival of other intertidal species and, therefore, strongly influences the structure and functioning of intertidal ecosystems (Jenkins *et al*., 2008).

Resilience and recovery rates of habitat

There is a lack of information on the life history traits of *Ascophyllum nodosum* ecad *mackayi*. Hence, much of this resilience assessment is based on *Ascophyllum nodosum*. As *Ascophyllum nodosum* ecad *mackayi* is created by environmental conditions, rather than the genetics, this resilience assessment should still be suitable, as many of the species traits will be the same.

The formation of this biotope relies on a supply of fragments from the attached form of this species. Once formed, the ecad can proliferate vegetatively from its own broken fragments. However, sexual reproduction results in germlings of attached *Ascophyllum nodosum* algae. Adult algae within the biotope may supply fragments for the creation of further ecad plants. Young ecad plants can produce receptacles frequently, but as the plant ages, it produces receptacles less frequently (Gibb, 1957). Gibb (1957) reported growth rates of *Ascophyllum nodosum* ecad *mackayi* at 5.4 cm/annum from four locations in Scotland. Differences in growth rates between shores were not considered significant. However, ecads higher up the shore were found to grow slower than those found further down the shore. Growth rates were slowest during winter, with little more than 1 cm in three months (Gibb, 1957). The increase in mass per annum varies but appears to have no direct relationship with tidal height (Gibb, 1957). This is except for those individuals found on the highest part of the shore that always showed stunted growth (Gibb, 1957). The greatest average percentage increase in mass per annum recorded by Gibb (1957) was 312%. The lowest average percentage increase on the same shore (Loch Ainort) was 20% (Gibb, 1957). Brinkhuis & Jones (1976) recorded growth rates of *Ascophyllum nodosum* ecad *mackayi* from a salt marsh in on the east coast of the USA. The growth rates recorded from these ecads was much faster than those recorded by Gibb (1957). Brinkhuis & Jones (1976) recorded *Ascophyllum nodosum* ecad *mackayi* growth rates of 10 cm in 4.5 months.

The lifespan of *Ascophyllum nodosum* ecad *mackayi* has not been investigated. Therefore, it is assumed to be similar to that of the fronds of the attached *Ascophyllum nodosum.* The survival of fronds of the attached form of *Ascophyllum nodosum* is 15 – 20 years (Åberg, 1992).

Recovery times for *Ascophyllum nodosum* ecad *mackayi* depend on how much of the raft was removed by a pressure, the location of the nearest *Ascophyllum nodosum* bed, and the level of fragment transport to the cleared area. Hence, recovery time is highly specific to each example of this biotope. Brinkhuis & Jones (1976) suggested that fragments of *Ascophyllum nodosum* travelled as far as 15 miles during winter storms to repopulate *Ascophyllum nodosum* ecad *mackayi* habitats in the USA. The only available record of the removal of an *Ascophyllum nodosum* ecad *mackayi* bed comes from the west coast of Scotland. The construction of the Skye Bridge resulted in the accidental, complete removal of a dense bed of *Ascophyllum nodosum* ecad *mackayi* at the Kyle of Lochalsh. No sign of recovery of this bed was noted more than two years later (Mathieson, 2009).

Resilience assessment. *Ascophyllum nodosum* as a species has low dispersal abilities, high juvenile mortality rates and can take in excess of five years to reach reproductive maturity. If a pressure causes a mass mortality event on a shore an *Ascophyllum nodosum* canopy can take twelve years to recover. This recovery depends on mature populations of the macroalgae in the vicinity from which to recruit. If a partial damage occurs to a frond but the holdfast and 15 cm – 25 cm of the thallus and remain, then recovery of an individual can occur within two to three years. Evidence suggests that even after the recovery of an *Ascophyllum nodosum* population the understory communities and ecosystem functioning of the area can take in excess of twenty years (Jenkins *et al*., 2004).

Ascophyllum nodosum ecad *mackayi* are only created when fragments of the attached form are transported into the correct environmental conditions. This creates an extra variable that is hard to account for within an estimation of recovery time of an *Ascophyllum nodosum* ecad *mackayi* bed. If a pressure has not affected the source of *Ascophyllum nodosum* fragments responsible for creating an *Ascophyllum nodosum* ecad *mackayi* raft, and transport of fronds to the 'suitable location' is frequent, recovery may be faster than expected from the removal of an *Ascophyllum nodosum* biotope. Alternatively, if a pressure does not entirely remove the raft then *Ascophyllum nodosum* ecad *mackayi* can vegetatively replace parts of the raft from its own broken fragments. However, there are no examples of recovery of an *Ascophyllum nodosum* ecad *mackayi* where either all or part of the raft is removed. It is not known if *Ascophyllum nodosum* ecad *mackayi* can recover from complete or partial removal. Due to the lack of direct evidence for this biotope, the long periods of time it takes for *Ascophyllum nodosum* to recover, the slow rates of reproduction, the stochastic nature of fragmentation and deposition in suitable habitat, the resilience of this biotope is probably at least 'Low' (10-25 years) and potentially 'Very Low' (>25 years).

Note. 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 recognisable 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)	Medium Q: High A: High C: High	Low Q: Medium A: Low C: Low	Medium Q: Medium A: Low C: Low

Schonbeck & Norton (1979) demonstrated that fucoids can increase tolerance in response to a gradual change in temperature through a process known as 'drought hardening'. However, acute changes in temperatures may cause damage to macroalgae and other species. In the British Isles *Ascophyllum nodosum* ecad *mackayi* is most abundant in Scotland, with rare records further south. It is likely that the range of ecad *mackayi* is not restricted by environmental tolerance. Instead, it is restricted due to a lack of suitable environmental conditions. However, the temperature tolerance of *Ascophyllum nodosum* ecad *mackayi* has not been investigated. *Ascophyllum nodosum* is found in the middle of its range in the British Isles, with populations in the North East Atlantic as far south as Portugal and extending north to the White Sea. Temperature ranges of species may not accurately describe their ability to withstand localized changes in temperature. However, they will display the limits of the species genetic ability to acclimatize to temperatures.

Hawkins & Hartnoll (1985) reported that fucoids are intolerant of sudden changes in temperature and relative humidity observing that bleaching and death of plants occurred during periods of hot weather. Gibb (1957) reported that *Ascophyllum nodosum* ecad *mackayi* is affected by 'sun' decay at the upper limit of the ecad zone. This decay could be partially due to an increase in the temperature causing an increase in desiccation.

Ascophyllum nodosum can tolerate certain levels of exposure as they are regularly exposed to rapid and short-term variations in temperature. Both exposure at low tide or rising tide on a sun-heated shore involves considerable temperature changes, and during winter the air temperature may be far below freezing point. The growth of *Ascophyllum nodosum* has been measured between 2.5 and 35°C with an optimum between 10 and 17°C (Strömgren, 1977). *Ascophyllum nodosum* can be damaged by thermal pollution if the water temperature remains above 24°C for several weeks (Lobban & Harrison, 1997), temperatures exceeding 27°C cause direct mortality (Keser *et al.*, 2005). Water temperature is an excellent predictor of gamete release in *Ascophyllum* (Bacon & Vadas, 1991). Consequently, changes in temperatures could impact on gamete release. Investigations into the tolerance of *Ascophyllum nodosum* germlings from Norway, to temperatures between 7°C -17°C found that there was no difference in survival rates within the given range (Steen & Rueness, 2004). Germination of *Ascophyllum nodosum* has been recorded between the temperatures of 4°C - 23°C.

Sensitivity assessment. The characterizing species *Ascophyllum nodosum* ecad *mackayi* is found almost exclusively in more northerly areas of the British Isles but is unlikely that the ecad *mackayi* is restricted by thermal tolerance. The range of the attached form of *Ascophyllum nodosum* can extend down to Portugal. If the temperature changes are acute and there is no time for acclimation then there could be some damage caused to the macroalgae. However, if the changes are more gradual then the algae may have time to acclimate. An increase in temperature at the benchmark may decrease the abundance of *Ascophyllum nodosum* ecad *mackayi* at the top of the ecad zone. The sensitivity assessment gives the resistance as 'Medium' and resilience of 'Low'. Meaning that the biotope sensitivity is 'Medium' to this pressure at the benchmark.

Temperature decrease (local)	Medium Q: High A: High C: High	Low Q: Medium A: Low C: Low	Medium Q: Medium A: Low C: Low

Acute changes in temperatures may cause damage to macroalgae and other species. In the British Isles *Ascophyllum nodosum* ecad *mackayi* is most abundant in Scotland. The distribution of ecad *mackayi* extends up into Scandinavia (Gibb, 1957), where winter temperatures are much lower. *Ascophyllum nodosum* is found in the middle of its range in the British Isles, with populations in the North East Atlantic as far south as Portugal and extending north to the White Sea. Although temperature ranges of species may not accurately describe their ability to withstand localized changes in temperature. They will display the limits of the species genetic ability to acclimatize to temperatures.

Ascophyllum nodosum can tolerate certain levels of exposure as they are regularly exposed to rapid and short-term variations in temperature. Tidal exposure during winter can expose the macroalgae to air temperatures may be far below freezing point. Growth of *Ascophyllum nodosum* has been measured between 2.5 and 35°C with an optimum between 10 and 17°C (Strömgren, 1977). *Ascophyllum nodosum* can be damaged by thermal pollution if the water temperature remains above 24°C for several weeks (Lobban & Harrison, 1997), temperatures exceeding 27°C cause direct mortality (Keser *et al*., 2005). Water temperature is an excellent predictor of gamete release in *Ascophyllum* (Bacon & Vadas, 1991). Consequently changes in temperatures could impact on gamete release. Investigations into the tolerance of *Ascophyllum nodosum* germlings from Norway, to temperatures between 7°C -17°C found that there was no difference in survival rates within the given range (Steen & Rueness, 2004). Germination of *Ascophyllum nodosum* has been recorded between the temperatures of 4°C - 23°C.

Sensitivity assessment. The characterizing species *Ascophyllum nodosum* ecad *mackayi* is found almost exclusively in more northerly areas of the British Isles. Examples of *Ascophyllum nodosum* ecad *mackayi* are found further north in Scandinavia. The range of the attached form of *Ascophyllum nodosum* can extend up to the White Sea. If the temperature changes are acute and there is no time for acclimation then there could be some damage caused to the macroalgae. However, there is no direct evidence on the effect of a decrease in temperature at the benchmark on *Ascophyllum nodosum* ecad *mackayi*. Both resistance and resilience are assessed as 'High', resulting in the biotope having a rating of 'Not Sensitive' to the pressure at this benchmark.

Salinity increase (local)	High Q: High A: High C: High	High Q: Medium A: Low C: Low	Not sensitive Q: Medium A: Low C: Low

Ascophyllum nodosum fragments transported to a suitable location begin to develop into the ecad form beginning with the branching of the fronds (Mathieson, 2009). Regular fluctuations between saline and freshwater are necessary for *Ascophyllum nodosum* ecad *mackayi* to form (Gibb, 1957). The greater the range in salinity within the environment the greater the regularity of the branching, and the faster the ecad form can develop (Gibb, 1957). *Ascophyllum nodosum* ecad *mackayi* was found to develop the fastest when located at mid tide level on the shore and inundated with freshwater during emersion (Gibb, 1957). Although salinity fluctuations are vital for the development of *Ascophyllum nodosum* ecad *mackayi*, once an ecad has developed it can survive in situations where salinity remains high (Gibb, 1957). Shore location also plays an important role in the ecad's development and branching habit as it affects the amount of time the algae is exposed to low salinities within each tide. Algae on the mid shore have the greatest number of apical branches, with those on the low shore having the lowest number (Gibb, 1957). The most affective salinity regime for the growth of *Ascophyllum nodosum* ecad *mackayi* is not known. Gibb (1957) notes that within each tidal cycle *Ascophyllum nodosum* ecad *mackayi* will spend time exposed to different salinities, but that it is the fluctuation in salinity appears to be important. Salinity regimes will vary constantly depending on a combination of tidal cycle I.e. springs or neaps, and weather conditions.

Sensitivity assessment. For *Ascophyllum nodosum* ecad *mackayi to* form fluctuations in salinity are required (Gibb, 1957). The salinity regimes within these biotopes will naturally fluctuate with tides and weather. Already formed *Ascophyllum nodosum* ecad *mackayi* (I.e. has already branched) can survive without a freshwater influence (Gibb, 1957). However if a freshwater influence were to disappear from the biotope 'new' *Ascophyllum nodosum* ecad *mackayi* would not form. Therefore, for the purpose of this assessment an increase in the salinity regime to fully marine for a year would not have a negative impact on this biotope. If the period of time for which the regime was entirely marine were to increase, no new *Ascophyllum nodosum* ecad *mackayi* could form resulting in the loss of the characterizing species and the biotope. For this assessment both resistance and resilience are assessed as 'High' resulting in this biotope being 'Not Sensitive' at the pressure benchmark.

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

Ascophyllum nodosum fragments transported to a suitable location begin to develop into the ecad form beginning with the branching of the fronds (Mathieson, 2009). Regular fluctuations between saline and freshwater are necessary for *Ascophyllum nodosum* ecad *mackayi* to form (Gibb, 1957). The greater the range in salinity within the environment the greater the regularity of the branching, and the faster the ecad form can develop (Gibb, 1957). *Ascophyllum nodosum* ecad *mackayi* was found to develop the fastest when located at mid tide level on the shore and inundated with freshwater during emersion (Gibb, 1957). Although salinity fluctuations are vital for the development of *Ascophyllum nodosum* ecad *mackayi*, once an ecad has developed it can survive in situations where salinity remains high (Gibb, 1957). Shore location also plays an important role in the ecad's development and branching habit as it affects the amount of time the algae is exposed to low salinities within each tide. Algae on the mid shore have the greatest number of apical branches, with those on the low shore having the lowest number (Gibb, 1957). The most affective salinity regime for the growth of *Ascophyllum nodosum* ecad *mackayi* is not known. Gibb (1957) notes that within each tidal cycle *Ascophyllum nodosum* ecad *mackayi* will spend time exposed to different salinities, but that it is the fluctuation in salinity appears to be important. Salinity regimes will vary constantly depending on a combination of tidal cycle i.e. springs or neaps, and weather conditions.

Sensitivity assessment. For *Ascophyllum nodosum* ecad *mackayi to* form fluctuations in salinity are required (Gibb, 1957). The salinity regimes within these biotopes will naturally fluctuate with tides and weather. But the effect of lowering the salinity, is not known. The greater the range of salinity the greater the regularity of branching is. Consequently a decrease in the range could decrease the rate of branching and have an effect on mass gain and growth rates. A decrease in the salinity regime will not cause mortality as *Ascophyllum nodosum* is able to survive in reduced salinity regimes. For the pressure at this benchmark there would be no significant effect on the characterizing species or the biotope. If the period of time for which the regime was to change were increased, the rate at which *Ascophyllum nodosum* ecad *mackayi* could form may slow down resulting in a decrease in the density of the characterizing species. For this assessment both resistance and resilience are assessed as 'High' resulting in this biotope being 'Not Sensitive' at the pressure benchmark.

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

This biotope occurs in conditions with weak (<0.5 m/s) or very weak (negligible) tidal streams (Connor *et al*., 2004), characteristic of the upper reaches of sea lochs. These conditions are mandatory because *Ascophyllum nodosum* ecad *mackayi* is unattached. Therefore the biotope is likely to be highly intolerant of an increase in water flow rate because the characterizing species will be washed away. Gibb (1957) noted that beds of the ecad were relatively stable, because the individual ecads interlock to form a raft. Individual fronds on the bottom of the raft may become embeded in the underlying mud and provide a modicum of attachment (although buried fronds decay). A single report noted that a lower shore mussel bed secured the bed of the ecad with their byssus threads. Nevertheless, it is probable that if water flow increased over 0.5 m/s the ecad could be washed away from the affected area. The attached form of *Ascophyllum nodosum* and the other algae species found within the biotope are able to tolerate higher water flow rates than the unattached ecad.

Sensitivity assessment. The biotope is only found in areas of weak to negligible water flow, so that an increase in water flow could remove all or a proportion of the bed. A further decrease in water flow is not relevant and not assessed. Therefore, a resistance of 'Low' is suggested at the benchmark level (increase of 0.1-0.2 m/s) to represent to potential loss of a proportion of the bed. As resilience is probably at least 'Low', sensitivity is likely to be 'High'.

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

Ascophyllum nodosum ecad *mackayi* becomes exposed to air during tidal cycles and is tolerant of some desiccation. However, Lüning (1990) noted that *Ascophyllum nodosum* is not normally exposed to air for than a few hours. An increase in emersion at the level of the benchmark would subject the species to greater desiccation and nutrient stress, and could kill plants at the upper end of the populations range depressing the upper limit. Gibb (1957) reported that *Ascophyllum nodosum* ecad *mackayi* is affected by 'sun' decay at the upper limit of the ecad zone. Ecads within this upper zone can suffer during periods of bright sunlight, after which sections of fronds can die and shed off, leaving the remaining tissue thinner and more fragile (Gibb, 1957).

Macrofauna, such as the gammarid amphipod *Hyale prevostii*, that use the algae as a sheltered and humid habitat are also intolerant of increased desiccation and will be likely to move down the shore to avoid the change in environmental conditions. Other species such as the periwinkle *Littorina littorea* are able to tolerate some increase in desiccation and will be little affected.

Sensitivity assessment. This pressure is likely to adjust the position of the biotope on the shore, but unlikely to cause large scale mortality. The upper and lower limits of the biotope will change but recovery may be comparatively quick from this pressure as it will allow recovery of *Ascophyllum nodosum* ecad *mackayi* through its ability to proliferate vegetatively from its own broken fragments forming new plants. However, the speed at which this could happen is not known. The resistance is 'Medium' and resilience is considered to be 'Low'. The overall sensitivity of this biotope is 'Medium'.

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

This biotope only occurs in extremely sheltered locations (Connor *et al*., 2004) characteristic of the upper reaches of sea lochs.. These conditions are mandatory because *Ascophyllum nodosum* ecad *mackayi* is unattached. Therefore the biotope is likely to be highly intolerant of an increase in wave height because the characterizing species may be removed from the site. The attached form of *Ascophyllum nodosum* and the other algae species found within the biotope are able to tolerate higher levels of water movement than the unattached ecad.

Sensitivity assessment. A decrease in wave exposure is unlikely to be relevant, although if it occurred over a large area, a decrease may favour the spread of the biotope. Gibb (1957) noted that winter storms can partially or fully remove beds. If wave exposure increased to very sheltered, sheltered or moderately exposed, the ecad bed and biotope would be lost. Therefore, although the benchmark represent a minor change in significant wave height, even a small increase in significant wave height or wave exposure is likely to be detrimental. Therefore a resistance of 'Low' is suggested. As the resilience is probably at least 'Low', the sensitivity is 'High'. If the relative wave height increases above a certain point then the characterizing species will disappear. However, the natural wave exposure range of this biotope is considered to exceed changes (increases and decreases) at the pressure benchmark. Consequently this biotope is considered to have 'High' resistance and resilience (by default), to this pressure (at the benchmark) and the sensitivity of this biotope is 'Not Sensitive'.

Chemical Pressures

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

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

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.

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.

Radionuclide contamination	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.

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

This pressure is **Not assessed**.

De-oxygenation	Medium Q: High A: Medium C: High	High Q: Low A: Low C: Low	Low Q: Low A: Low C: Low

Cole *et al*. (1999) suggested possible adverse effects on marine species below oxygen levels of 4 mg/l and probable adverse effects below 2 mg/l. Sustained reduction of dissolved oxygen can lead to hypoxic (reduced dissolved oxygen) and anoxic (extremely low or no dissolved oxygen) conditions. Sustained or repeated episodes of reduced dissolved oxygen have the potential to severely degrade an ecosystem (Cole *et al*., 1999).

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). 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.

Josefson & Widbom (1988) investigated the response of benthic macro and meiofauna to reduced dissolved oxygen levels in the bottom waters of a fjord. At dissolved oxygen concentrations of 0.21 mg/l, the macrofaunal community was eradicated and was not fully re-established 18 months after the hypoxic event. However, meiofauna seemed, unaffected by de-oxygenation. Kinne (1970) reported that reduced oxygen concentrations inhibit both algal photosynthesis and respiration. However, *Arenicola marina* has been found to be unaffected by short periods of anoxia and to survive for 9 days without oxygen (Borden, 1931 and Hecht, 1932 cited in Dales, 1958; Hayward, 1994), while no evidence on the tolerance of other infauna e.g. *Lanice conchilega* was available.

The very sheltered to extremely sheltered and the weak to very weak tidal flows which are characteristic of this biotope means that water mixing is minimal. Therefore water movement within this area will not reverse any oxygen depletion quickly. But the biotope occurs in the mid eulittoral so that a proportion of time will be spent in the air where oxygen is not limited so the metabolic processes of photosynthesis and respiration can take place.

Sensitivity assessment. The characterizing species *Ascophyllum nodosum* ecad *mackayi* and the associated community within this biotope could be negatively impacted by reduced dissolved oxygen level at the level of the benchmark (2 mg/l for 1 week). A reduction in oxygen levels at the benchmark for this pressure would probably result in some mortality of the associated invertebrate community of littorinids and amphipod grazers. The extremely wave sheltered locations in which this biotope is found will mean that very little water mixing will take place and deoxygenated water will not be removed from the shore quickly. Therefore, resistance is assessed as 'Medium'. However, the associated community of mobile fauna will probably return quickly (within a year) and resilience is assessed as 'High'. Giving the biotope a sensitivity score of 'Low'.

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

The nutrient enrichment of a marine environment leads to organisms no longer being limited by the availability of certain nutrients. The consequent changes in ecosystem functions can lead to the progression of eutrophic symptoms (Bricker *et al.*, 2008), changes in species diversity and evenness (Johnston & Roberts, 2009) decreases in dissolved oxygen and uncharacteristic microalgae blooms (Bricker *et al.*, 1999, 2008).

Johnston & Roberts (2009) undertook a review and meta-analysis of the effect of contaminants on species richness and evenness in the marine environment. Of the 47 papers reviewed relating to nutrients as contaminants, over 75% found that it had a negative impact on species diversity, <5% found increased diversity, and the remaining papers finding no detectable effect. Not all of the 47 papers considered the impact of nutrients on intertidal rocky shores. Yet this finding is still relevant as the meta-analysis revealed that the effect of marine pollutants on species diversity was 'remarkably consistent' between habitats (Johnston & Roberts, 2009). It was found that any single pollutant reduced species richness by 30-50% within any of the marine habitats considered (Johnston & Roberts, 2009). Throughout their investigation, there were only a few examples where species richness was increased due to the anthropogenic introduction of a contaminant. These examples were almost entirely from the introduction of nutrients, either from aquaculture or sewage outfalls. However, research into the impacts of nutrient enrichment from these sources on intertidal rocky shores often lead to shores lacking species diversity and the domination by algae with fast growth rates (Abou-Aisha *et al.*, 1995, Archambault *et al.*, 2001, Arévalo *et al.*, 2007, Diez *et al.*, 2003, Littler & Murray, 1975).

White *et al.*, (2011) investigated the effects of nutrient effluent from land-based finfish farms on the morphologies of *Ascophyllum nodosum* in the vicinity of the outfall pipes. It was estimated that the nitrogen effluent from the farm was 1500 kg y^{-1}. The background levels of nitrite at the test site were 300 □M, in comparison, the ambient nitrite levels in southwest Nova Scotia are 3 □M (White *et al.*, 2011). The *Ascophyllum nodosum* that were at the test sites were found to be younger than those at the control sites, but significantly larger. This experiment showed that nutrient effluent could have positive impacts on *Ascophyllum nodosum*. Yet it must be noted that the effect of the effluent on the rest of the biological community was not studied.

Changes in community composition on intertidal rocky shores can happen rapidly, and fast-growing ephemeral species can become established quickly in the presence of higher concentrations of nutrients. The establishment and growth of these species are not controlled by wave exposure (Kraufvelin, 2007). However, even though these fast-growing ephemeral species can become well established quickly, healthy communities on intertidal rocky shores can survive long periods of time, and maintain ecological function after these species have become established

(Bokn *et al*., 2002, 2003, Karez *et al*.,2004, Kraufvelin, 2007, Kraufvelin *et al*., 2006).

Sensitivity assessment. A slight increase in nutrients may enhance growth rates but high nutrient concentrations could lead to the overgrowth of the algae by ephemeral green algae and an increase in the number of grazers. However, if the biotope is well established and in a healthy state, the biotope could have the potential to persist. However, the biotope is regarded as 'Not sensitive' at the pressure benchmark of compliance with good status as defined by the WFD.

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

The organic enrichment of a marine environment at this pressure benchmark leads to organisms no longer being limited by the availability of organic carbon. The consequent changes in ecosystem functions can lead to the progression of eutrophic symptoms (Bricker *et al*., 2008), changes in species diversity and evenness (Johnston & Roberts, 2009) and decreases in dissolved oxygen and uncharacteristic microalgae blooms (Bricker *et al*., 1999, 2008).

Johnston & Roberts (2009) undertook a review and meta-analysis of the effect of contaminants on species richness and evenness in the marine environment. Of the 49 papers reviewed relating to sewage as a contaminant, over 70% found that it had a negative impact on species diversity, <5% found increased diversity, and the remaining papers finding no detectable effect. Not all of the 49 papers considered the impact of sewage on intertidal rocky shores. Yet this finding is still relevant as the meta-analysis revealed that the effect of marine pollutants on species diversity was 'remarkably consistent' between habitats (Johnston & Roberts, 2009). It was found that any single pollutant reduced species richness by 30-50% within any of the marine habitats considered (Johnston & Roberts, 2009). Throughout their investigation, there were only a few examples where species richness was increased due to the anthropogenic introduction of a contaminant. These examples were almost entirely from the introduction of nutrients, either from aquaculture or sewage outfalls. However, research into the impacts of organic enrichment from these sources on intertidal rocky shores often lead to shores lacking species diversity and the domination by algae with fast growth rates (Abou-Aisha *et al*., 1995, Archambault *et al*., 2001, Arévalo *et al*., 2007, Diez *et al*., 2003, Littler & Murray, 1975).

Nutrient enrichment alters the selective environment by favouring fast growing, ephemeral species such as *Ulva lactuca* and *Ulva intestinalis* (Berger *et al*., 2004, Kraufvelin, 2007). Rohde *et al*. (2008) found that both free growing filamentous algae and epiphytic microalgae can increase in abundance with nutrient enrichment. This stimulation of annual ephemerals may accentuate the competition for light and space and hinder perennial species development or harm their recruitment (Berger et al., 2003; Kraufvelin *et al*., 2007). Nutrient enrichment can also enhance fouling of fucoid fronds by biofilms (Olsenz, 2011). Nutrient enriched environments can not only increase algae abundance but the abundance of grazing species (Kraufvelin, 2007). Bellgrove *et al*. (2010) found that coralline turfs out-competed fucoids at a site associated with organic enrichment caused by an ocean sewage outfall.

Changes in community composition on intertidal rocky shores can happen rapidly, and fast-growing ephemeral species can become established quickly in the presence of higher concentrations of nutrients. The establishment and growth of these species are not controlled by wave exposure (Kraufvelin, 2007). However, even though these fast-growing ephemeral species can become well established quickly, healthy communities on intertidal rocky shores can survive long periods of time, and maintain ecological function after these species have become established

(Bokn *et al.*, 2002, 2003, Karez *et al.*,2004, Kraufvelin, 2007, Kraufvelin *et al.*, 2006).

Sensitivity assessment. Little empirical evidence was found to support an assessment of this biotope at this benchmark. Due to the potential negative impacts that have been reported to result from the introduction of excess organic carbon, resistance has been assessed as 'Medium' and resilience has been assessed as 'Low'. This gives an overall sensitivity score of 'Medium'.

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)	High Q: High A: High C: High	High Q: Medium A: Low C: Low	Not sensitive Q: Medium A: Low C: Low

This biotope is only recorded from pebbles and cobbles with mud and sand, i.e. mixed sediment habitats. The biotope is dependent on the extremely wave sheltered, low tidal flow, variable salinity and relatively shallow slope shores, typical of the upper reaches of sea lochs. However, the development of the biotope is probably not dependent on the nature of the substratum itself, but that the conditions that favour the biotope also favour mixed sediment shores. Therefore, it is probably not sensitive to changes in the substratum itself, as long as the other habitat requirements are met. However, infauna would be lost while the biotope would remain. Therefore, resistance is probably 'High, resilience 'High' and the biotope 'Not sensitive' to this pressure.

	Resistance	Resilience	Sensitivity
Physical change (to another sediment type)	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

The sediment associated with this biotope is described as cobbles and pebbles on mud and sand. The characterizing species, *Ascophyllum nodosum* ecad *mackayi* isn't attached to the substratum and is free floating. Therefore if the substratum were to change this wouldn't have a negative effect on the characterizing species. The other species within the associated community depend on different aspects of the sediment. Those species which are found in the finer sediments may change if there was a change in Folk class. For example, the sediment habitat in which *Arenicola marina* and *Lanice conchilega* may no longer be suitable after a change in Folk class and may be lost from the biotope.

Sensitivity assessment. A change in this pressure at the benchmark will not affect the characterizing species. Resistance and resilience are assessed as 'High', resulting in a 'Not Sensitive' assessment.

Habitat structure changes - removal of substratum (extraction)	Low Q: High A: High C: High	Low Q: Medium A: Low C: Low	High Q: Medium A: Low C: Low

Although *Ascophyllum nodosum* ecad *mackayi* is unattached the species is likely to be removed along with substrata. The rest of the biological community found within this biotope would also be removed along with the substratum.

Sensitivity assessment. Due to the nature of this pressure, it is highly likely that a large amount of the sediment would be removed along with the biological community. Resistance and resilience have been assessed as 'Low' with a sensitivity of 'High'.

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

This biotope is found on the mid-tidal shore. An area easily accessible by humans especially at low tide. Although individual macroalgae are flexible they are not physically robust. Mathieson (unpublished; taken from Mathieson, 2009) reports that in Loch Sunart winkle pickers deliberately target *Ascophyllum nodosum* ecad *mackayi* beds. Although not experimentally investigated the effect of winkle pickers on the shore is likely to damage the fronds of *Ascophyllum nodosum* ecad *mackayi.*

Trampling on the rocky shore has been found to reduce fucoid cover (Holt *et al.*, 1997, Brosnan, 1993, Flether & Frid, 1996; Tyler-Walters & Arnold, 2008)). A loss of fucoids decreases the microhabitat available for epiphytic species, increases the amount of bare substrate and can increase the cover of opportunistic species such as *Ulva* (Fletcher & Frid, 1996a).

As few as 20 steps / m^2 on stations on an intertidal rocky shore in the north east of England were sufficient to reduce the abundance of fucoids (Fletcher & Frid, 1996a). This reduction in the complexity of the algae community, in turn, reduced the microhabitat available for epiphytic species. Trampling pressure can thus result in an increase in the area of bare rock on the shore (Hill *et al.*, 1998). Chronic trampling can affect community structure with shores becoming dominated by algal turf or crusts (Tyler-Walters, 2005). Pinn & Rodgers (2005) compared the biological communities found on two intertidal rocky shore ledges in Dorset. They found that the ledge which had a higher number of visitors had few branching algal species, including fucoids, but had greater abundances of crustose and ephemeral species (Pinn & Rodgers, 2005). The densities of fucoids were recorded from the intertidal rocky shore at Wembury, Devon in 1930 (Colman, 1933) and 1973 (Boalch *et al.*, 1974). Boalch *et al.* (1974) found a reduction in fucoids on the shore at Wembury and that the average frond length of *Ascophyllum nodosum* was smaller.

Ascophyllum nodosum seems to be particularly intolerant of damage from trampling (Flavell, Unpublished cited in Holt *et al.*, 1997). It is also likely to be removed if shores are mechanically cleaned following oil spills. Araujo *et al.* (2009) found that trampling negatively affected both *Ascophyllum nodosum* abundances and reduced understorey species while promoting the colonization by ephemeral green algae. However, within a year of the disturbance event, *Fucus vesiculosus* had become the dominant canopy forming species, replacing a pre-disturbance *Ascophyllum nodosum* community. The replacement of *Ascophyllum nodosum* with *Fucus vesiculosus* may have been due to the poor recovery rate of *Ascophyllum nodosum.* Rita *et al.*, (2012) also undertook experiments on the effect of trampling on *Ascophyllum nodosum* and its associated communities. It was concluded that trampling caused significant damage to both the macroalgae and the understory communities, which had not recovered within five years of the initial experiment.

Sensitivity assessment. Although this species is not attached to the substratum directly it does rest on the intertidal shore as the tide recedes. Anything then travelling over the shore would crush the fronds of the algae against the substratum. Intertidal species collection in Loch Sunart is such an activity that would cause damage through trampling. *Ascophyllum nodosum* ecad *mackayi* is likely to have very similar tolerances to trampling as the attached form. Therefore, the resistance is probably 'Low', resilience is a least 'Low', giving a sensitivity of 'High'.

Penetration or disturbance of the substratum subsurface	Low Q: High A: Medium C: Medium	Low Q: Medium A: Low C: Low	High Q: Medium A: Low C: Low

Although *Ascophyllum nodosum* ecad *mackayi* is not attached to the seabed, it does rest on the shore during low tides. For damage to occur to the sub-surface seabed within this biotope, the pressure would have to pass through the biological community i.e. the majority of the species, including the characterizing species *Ascophyllum nodosum* ecad *mackayi*, lay on top of, or are attached to the substratum. Therefore, the assessment for abrasion at the surface is considered to represent this biotopes sensitivity at this pressure.

Changes in suspended solids (water clarity)	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

Light is an essential resource for all photoautotrophic organisms and a change in turbidity would affect light availability to photosynthesising organisms during immersion which could result in reduced growth rates. *Ascophyllum nodosum* ecad *mackayi* is a free-living form and floats on water. Therefore, it is always found at the top of the water column and is unlikely to be affected by a change in this pressure at the benchmark. *Ascophyllum nodosum* ecad *mackayi* will also be able to continue to photosynthesize at low tide when the plants are emersed, as long as the plant has a sufficiently high water content (Beer & Kautsky, 1992).

A reduction in light levels due to an increase in the level of suspended sediment will not have a negative impact on the fauna within this biotope, and it is unlikely to have a significant negative impact on the other flora species, due to the intertidal nature of the biotope. An increase in levels of suspended sediment could potentially be beneficial to filter feeding organisms.

Sensitivity assessment. A change in this pressure at the benchmark is unlikely to have any negative impact on this biotope. Consequently, the resistance and resilience of this biotope have been assessed as 'High'. The sensitivity of this biotope to this pressure at the benchmark is 'Not Sensitive'.

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

A discrete event where sediment inundates this biotope to 5 cm will have very different effects on the characterizing species and the associated community depending on the state of the tide. High tide will mean that the characterizing species will be off the substratum, as it is a free-floating form. Therefore the sediment deposition would not smother any of the *Ascophyllum nodosum* ecad *mackayi* raft or the associated epiphytic species.

In contrast, if the tide is out then fronds of the characterizing fucoid canopy will be flat on the substratum and will be smothered by the sediment deposit. The low water flow and wave sheltered physical conditions which are characteristic of this biotope mean that the sediment will not be removed from the shore quickly. Smothering will prevent photosynthesis resulting in reduced growth and eventually death. Observations on *Ascophyllum nodosum* ecad *mackayi* have reported that the lower fronds of the organism can occasionally become buried in soft mud. These fronds soon decay and die (Gibb, 1957). Smothering at this benchmark is likely to cause mortality of the characterizing species.

Sensitivity assessment. The pressure at this benchmark will have a negative impact on the biological community of this biotope if the tide is out when the sediment is deposited. *Ascophyllum nodosum* ecad *mackayi* is smothering intolerant, and fronds start to decompose quickly. The very low levels of water movement within this biotope mean that sediment will not be quickly removed from the shore. Therefore, resistance is probably 'Low' as a proportion of the bed may be lost through decay. As resilience is probably at least 'Low', sensitivity is 'High'.

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

Increasing the vertical sediment burden will increase the level of mortality of the biological community within this biotope. At the level of the benchmark (30 cm of fine material added to the seabed in a single event), smothering is likely to result in mortalities of the characterizing algae, invertebrate grazers and young (germling) fucoids. The low levels of water movement will mean that sediment will remain within the biotope for an extended period of time. Resistance and resilience are assessed as 'Low' Overall the biotope have a 'High' sensitivity to siltation at the pressure benchmark.

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

Not assessed.

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

No evidence.

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

Species characterizing this habitat do not have hearing perception but vibrations may cause an impact, however, no studies exist to support an assessment.

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

Gibb (1957) reported that long periods of bright sunshine decreased the growth rate of *Ascophyllum nodosum* ecad *mackayi*, especially in those individuals found higher on the shore. Extended periods of bright sunlight were also reported to damage fronds, which would later be lost through decay (Gibb, 1957). In the British Isles *Ascophyllum nodosum* ecad *mackayi* is most abundant in Scotland, with rare records further south. It is likely that the range of this ecad is not restricted by environmental tolerance. Instead, it is restricted due to a lack of suitably sheltered environmental conditions. The attached form of *Ascophyllum nodosum* is found throughout the British Isles, therefore the ability to tolerate increased irradiance will be very similar. However, there is no quantifiable evidence available on the effect of this pressure on *Ascophyllum nodosum* ecad *mackayi*'. Shading by artificial structure (e.g. pontoons or jetties) could significantly reduce photosynthesis and hence growth in the affected area, and probably result in loss of the ecad due to decay in long-term. Therefore, a resistance of 'Low' is suggested (within the footprint of the activity). As resilience is probably at least 'Low' sensitivity is probably 'High'.

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

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

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

Not relevant.

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

Not relevant.

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not sensitive Q: NR A: NR C: NR

Key characterizing species within this biotope are not cultivated or translocated. This pressure is therefore considered 'Not relevant' to this biotope.

Introduction or spread of invasive non-indigenous species	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

Thompson & Schiel (2012) found that native fucoids show high resistance to invasions by the Japanese kelp *Undaria pinnatifida*. However, the cover of *Fucus vesiculosus* was inversely correlated with the cover of the invasive *Sargassum muticum* indicating a competitive interaction between the two species (Stæhr *et al*., 2000). Stæhr *et al*. (2000) determined that the invasion of *Sargassum muticum* could affect local algal communities through competition mainly for light and space.

Gracilaria vermiculophylla is suggested to be one of the most successful marine non-native species (Kim *et al*., 2010, Sfriso *et al*., 2010 taken from Thomsen *et al*., 2013). This species invades wave sheltered, shallow water areas, and have been found in biotopes naturally dominated by fucoid canopies (Weinberger *et al*., 2008). Hammann *et al*., (2013) found that in the Baltic Sea *Gracilaria vermiculophylla* could impact *Fucus vesiculosus* through direct competition for resources, decreasing the half-life of germlings, and increasing the level of grazing pressure. To date, *Gracilaria vermiculophylla* has only been recorded in Northern Ireland, and not on mainland Britain. The introduction of this species to intertidal rocky shores around the British Isles could have negative impacts on native fucoid biotopes and could become relevant to this specific biotope.

Sensitivity assessment. Fucoid species have been negatively affected by both the direct and indirect consequences of INNS being present. However, no evidence can be found on the impacts of INNS on *Fucus vesiculosus* and *Ascophyllum nodosum* within this biotope. Therefore, the effect of this pressure has been given as 'No Evidence'. Literature for this pressure should be revisited.

Introduction of microbial pathogens	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.

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

Seaweeds have been collected from the middle of the 16th century for the iodine industry. Modern day use Industrial uses for seaweed are extensive and include fertilizer, animal feed, alginate extracts (Phillipi *et al*., 2014), water treatment, and human food and health supplements (Bixler & Porse, 2010). *Ascophyllum nodosum* is harvested for commercial use in large quantities. Mathieson (2009) presented some anecdotal evidence of *Ascophyllum nodosum* ecad *mackayi* populations being 'decimated' through collection in the Uists.

Studies on the effects of commercial harvesting on the faunal communities associated with *Ascophyllum nodosum* have found that removing this key species can impact abundances of epifauna found on the un-harvested biomass (Jarvis & Seed, 1996, Johnson & Scheibling, 1987). Changes *Ascophyllum nodosum* have also been found to affect the large, mobile fauna such as crabs or grazing gastropods (Bertness *et al*., 1999; Fegley, 2001; Jenkins *et al*., 1999, 2004, Phillipi *et al*., 2014).

Although not all experiments have shown that harvesting has a negative impact on surrounding communities. Phillipi *et al.* (2014) replicated commercial harvesting techniques in Maine, the USA where *Ascophyllum nodosum* fronds were removed 40.6cm from the holdfast and the lowest lateral branch must remain with the holdfast (DMR, 2009). The experiment found that invertebrate species found living on and within sediments were not negatively affected by the harvesting activity (Phillipi *et al*., 2014).

Due to the intolerance of macroalgae communities to human exploitation, the European Union put in place a framework to regulate the exploitation of algae establishing an organic label that implies that 'harvest shall not cause any impact on ecosystems' (no. 710/2009 and 834/2007).

Sensitivity assessment. The removal of *Ascophyllum nodosum* ecad *mackayi* canopy would significantly change the community composition of the biotope. The quantity of biomass removed from the shore and the regularity of removal will all affect how the biotope will be able to recover. Therefore, resistance is probably 'Low' and resilience at least 'Low', resulting in a sensitivity of 'High'.

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

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The characterizing species *Ascophyllum nodosum* ecad *mackayi* creates a dominant canopy within this biotope. The dominance of this characterizing species means it could easily be incidentally removed from this biotope as by-catch when other species are being targeted. The loss of *Ascophyllum nodosum* ecad *mackayi* and other associated species would decrease species richness and negatively impact on the ecosystem function. For example, during the construction of the Skye Bridge, a dense bed of *Ascophyllum nodosum* ecad *mackayi* at Kyle of Lochalsh was completely removed (Mathieson, 2009). Two years after the removal, no recovery was observed.

Sensitivity assessment. Removal of a large percentage of the characterizing species would alter the character of the biotope. The resistance to removal is 'Low' due to the easy accessibility of the biotopes location and the inability of these species to evade collection. The resilience is 'Low', giving an overall sensitivity score of 'High'.

Bibliography

Åberg, P., 1992. Size-based demography of the seaweed *Ascophyllum nodosum* in stochastic environments. *Ecology*, **73:** 1488-1501.

Abou-Aisha, K.M., Kobbia, I., El Abyad, M., Shabana, E.F. & Schanz, F., 1995. Impact of phosphorus loadings on macro-algal communities in the Red Sea coast of Egypt. *Water, Air, and Soil Pollution*, **83** (3-4), 285-297.

Arévalo, R., Pinedo, S. & Ballesteros, E., 2007. Changes in the composition and structure of Mediterranean rocky-shore communities following a gradient of nutrient enrichment: descriptive study and test of proposed methods to assess water quality regarding macroalgae. *Marine Pollution Bulletin*, **55** (1), 104-113.

Araújo, R., Vaselli, S., Almeida, M., Serrão, E. & Sousa-Pinto, I., 2009. Effects of disturbance on marginal populations: human trampling on *Ascophyllum nodosum* assemblages at its southern distribution limit. *Marine Ecology Progress Series*, **378**, 81-92.

Archambault, P., Banwell, K. & Underwood, A., 2001. Temporal variation in the structure of intertidal assemblages following the removal of sewage. *Marine Ecology Progress Series*, **222**, 51-62.

Bacon, L.M. & Vadas, R.L., 1991. A model for gamete release in *Ascophyllum nodosum* (Phaeophyta). *Journal of Phycology*, **27**, 166-173.

Beer, S. & Kautsky, L., 1992. The recovery of net photosynthesis during rehydration of three *Fucus* species from the Swedish West Coast following exposure to air. *Botanica Marina*, **35** (6), 487-492.

Bellgrove, A., McKenzie, P.F., McKenzie, J.L. & Sfiligoj, B.J., 2010. Restoration of the habitat-forming fucoid alga *Hormosira banksii* at effluent-affected sites: competitive exclusion by coralline turfs. *Marine Ecology Progress Series*, **419**, 47-56.

Berger, R., Henriksson, E., Kautsky, L. & Malm, T., 2003. Effects of filamentous algae and deposited matter on the survival of *Fucus vesiculosus* L. germlings in the Baltic Sea. *Aquatic Ecology*, **37** (1), 1-11.

Bertness, M.D., Leonard, G.H., Levine, J.M., Schmidt, P.R. & Ingraham, A.O., 1999. Testing the relative contribution of positive and negative interactions in rocky intertidal communities. *Ecology*, **80** (8), 2711-27

Bixler, H.J. & Porse, H., 2010. A decade of change in the seaweed hydrocolloids industry. *Journal of Applied Phycology*, **23** (3), 321-335.

Boalch, G.T., Holme, N.A., Jephson, N.A. & Sidwell, J.M.C., 1974. A resurvey of Colman's intertidal traverses at Wembury, South Devon. *Journal of the Marine Biological Association of the United Kingdom*, **5**, 551-553.

Bokn, T.L., Duarte, C.M., Pedersen, M.F., Marba, N., Moy, F.E., Barrón, C., Bjerkeng, B., Borum, J., Christie, H. & Engelbert, S., 2003. The response of experimental rocky shore communities to nutrient additions. *Ecosystems*, **6** (6), 577-594.

Bokn, T.L., Moy, F.E., Christie, H., Engelbert, S., Karez, R., Kersting, K., Kraufvelin, P., Lindblad, C., Marba, N. & Pedersen, M.F., 2002. Are rocky shore ecosystems affected by nutrient-enriched seawater? Some preliminary results from a mesocosm experiment. *Sustainable Increase of Marine Harvesting: Fundamental Mechanisms and New Concepts:* Springer, pp. 167-175.

Bricker, S.B., Clement, C.G., Pirhalla, D.E., Orlando, S.P. & Farrow, D.R., 1999. National estuarine eutrophication assessment: effects of nutrient enrichment in the nation's estuaries. NOAA, National Ocean Service, Special Projects Office and the National Centers for Coastal Ocean Science, Silver Spring, MD, 71 pp.

Bricker, S.B., Longstaff, B., Dennison, W., Jones, A., Boicourt, K., Wicks, C. & Woerner, J., 2008. Effects of nutrient enrichment in the nation's estuaries: a decade of change. *Harmful Algae*, **8** (1), 21-32.

Brinkhuis, B.H. & Jones, R.F. 1976. The ecology of temperate saltmarsh fucoids. II. In situ growth of transplanted Ascophyllum nodosum ecads.

Chock, J.S. & Mathieson, A.C., 1976. Ecological studies of the salt marsh ecad *scorpioides* (Hornemann) Hauck of *Ascophyllum nodosum* (L.) Le Jolis. *Journal of Experimental Marine Biology and Ecology*, **23**, 171-190.

Cole, S., Codling, I.D., Parr, W. & Zabel, T., 1999. Guidelines for managing water quality impacts within UK European Marine sites. *Natura 2000 report prepared for the UK Marine SACs Project.* 441 pp., Swindon: Water Research Council on behalf of EN, SNH, CCW, JNCC, SAMS and EHS. [UK Marine SACs Project.], http://www.ukmarinesac.org.uk/

Colman, J., 1933. The nature of the intertidal zonation of plants and animals. *Journal of the Marine Biological Association of the United Kingdom*, **18**, 435-476.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B., 2004. The Marine Habitat Classification for Britain and Ireland. Version 04.05. ISBN 1 861 07561 8. In JNCC (2015), *The Marine Habitat Classification for Britain and Ireland Version 15.03.* [2019-07-24]. Joint Nature Conservation Committee, Peterborough. Available from https://mhc.jncc.gov.uk/

Dales, R.P., 1958. Survival of anaerobic periods by two intertidal polychaetes, *Arenicola marina* (L.) and *Owenia fusiformis* Delle Chiaje. *Journal of the Marine Biological Association of the United Kingdom*, **37**, 521-529.

Dıez, I., Santolaria, A. & Gorostiaga, J., 2003. The relationship of environmental factors to the structure and distribution of subtidal seaweed vegetation of the western Basque coast (N Spain). *Estuarine, Coastal and Shelf Science*, **56** (5), 1041-1054.

DMR, 2009. Laws and regulations, chapter 29 - seaweed. Department of Marine Resources, State of Maine. (Available from: http://www.maine.gov/dmr/commercialfishing/documents/seaweeds.graph.pdf).

Fegley, J., 2001. *Ecological implications of rockweed, Ascophyllum nodosum (L.) Le Jolis, harvesting.* University of Maine, Orono, ME.

Frieder, C., Nam, S., Martz, T. & Levin, L., 2012. High temporal and spatial variability of dissolved oxygen and pH in a nearshore California kelp forest. *Biogeosciences*, **9** (10), 3917-3930.

Gibb, D.C., 1957. The free-living forms of *Ascophyllum nodosum* (L.) Le Jolis. *Journal of Ecology*, **45**, 49-83.

Hammann, M., Buchholz, B., Karez, R. & Weinberger, F., 2013. Direct and indirect effects of *Gracilaria vermiculophylla* on native *Fucus vesiculosus*. *Aquatic Invasions*, **8** (2), 121-132.

Hawkins, S.J. & Hartnoll, R.G., 1985. Factors determining the upper limits of intertidal canopy-forming algae. *Marine Ecology Progress Series*, **20**, 265-271.

Hayward, P.J. 1994. *Animals of sandy shores.* Slough, England: The Richmond Publishing Co. Ltd. [Naturalists' Handbook 21.]

Hill, S., Burrows, S.J. & Hawkins, S.J., 1998. *Intertidal Reef Biotopes (Volume VI). An overview of dynamics and sensitivity characteristics for conservation management of marine Special Areas of Conservation.* Oban: Scottish Association for Marine Science (UK Marine SACs Project)., Scottish Association for Marine Science (UK Marine SACs Project).

Holt, T.J., Hartnoll, R.G. & Hawkins, S.J., 1997. The sensitivity and vulnerability to man-induced change of selected communities: intertidal brown algal shrubs, *Zostera* beds and *Sabellaria spinulosa* reefs. *English Nature, Peterborough, English Nature Research Report* No. 234.

Jarvis, S. & Seed, R., 1996. The meiofauna of *Ascophyllum nodosum* (L.) Le Jolis: characterization of the assemblages associated with two common epiphytes. *Journal of Experimental Marine Biology and Ecology*, **199**, 249-267.

Jenkins, S.R., Hawkins, S.J. & Norton, T.A., 1999. Direct and indirect effects of a macroalgal canopy and limpet grazing in structuring a sheltered inter-tidal community. *Marine Ecology Progress Series*, **188**, 81-92.

Jenkins, S.R., Moore, P., Burrows, M.T., Garbary, D.J., Hawkins, S.J., Ingólfsson, A., Sebens, K.P., Snelgrove, P.V., Wethey, D.S. & Woodin, S.A., 2008. Comparative ecology of North Atlantic shores: do differences in players matter for process? *Ecology*, **89** (11), 3-S23.

Jenkins, S.R., Norton, T.A. & Hawkins, S.J., 2004. Long term effects of *Ascophyllum nodosum* canopy removal on mid shore community structure. *Journal of the Marine Biological Association of the United Kingdom*, **84**, 327-329.

JNCC, 2015. The Marine Habitat Classification for Britain and Ireland Version 15.03. (20/05/2015). Available from https://mhc.jncc.gov.uk/

Johnson, S. & Scheibling, R., 1987. Structure and dynamics of epifaunal assemblages on intertidal macroalgae *Ascophyllum nodosum* and *Fucus vesiculousus* in Nova Scotia, Canada. *Marine Ecology Progress Series*, **37**, 209-227.

Johnston, E.L. & Roberts, D.A., 2009. Contaminants reduce the richness and evenness of marine communities: a review and meta-analysis. *Environmental Pollution*, **157** (6), 1745-1752.

Josefson, A. & Widbom, B., 1988. Differential response of benthic macrofauna and meiofauna to hypoxia in the Gullmar Fjord basin. *Marine Biology*, **100** (1), 31-40.

Karez, R., Engelbert, S., Kraufvelin, P., Pedersen, M.F. & Sommer, U., 2004. Biomass response and changes in composition of ephemeral macroalgal assemblages along an experimental gradient of nutrient enrichment. *Aquatic Botany*, **78** (2), 103-117.

Keser, M., Swenarton, J.T. & Foertch, J.F., 2005. Effects of thermal input and climate change on growth of *Ascophyllum nodosum* (Fucales, Phaeophyceae) in eastern Long Island Sound (USA). *Journal of Sea Research*, **54** (3), 211-220.

Kim, S.Y., Weinberger, F. & Boo, S.M., 2010. Genetic data hint at a common donor region for invasive Atlantic and Pacific population of Gracilaria vermiculophylla (Gracilariales, Rhodophyta) 1. *Journal of Phycology*, **46** (6), 1346-1349.

Kinne, O., 1977. International Helgoland Symposium "Ecosystem research": summary, conclusions and closing. *Helgoländer Wissenschaftliche Meeresuntersuchungen*, **30**(1-4), 709-727.

Kraufvelin, P., Moy, F.E., Christie, H. & Bokn, T.L., 2006. Nutrient addition to experimental rocky shore communities revisited: delayed responses, rapid recovery. *Ecosystems*, **9** (7), 1076-1093.

Kraufvelin, P., Ruuskanen, A., Nappu, N. & Kiirikki, M., 2007. Winter colonisation and succession of filamentous algae and possible relationships to *Fucus vesiculosus* settlement in early summer. *Estuarine Coastal and Shelf Science*, **72**, 665-674.

Littler, M. & Murray, S., 1975. Impact of sewage on the distribution, abundance and community structure of rocky intertidal macro-organisms. *Marine Biology*, **30** (4), 277-291.

Lobban, C.S. & Harrison, P.J., 1997. *Seaweed ecology and physiology*. Cambridge: Cambridge University Press.

Lüning, K., 1990. *Seaweeds: their environment, biogeography, and ecophysiology*: John Wiley & Sons.

Mathieson, S., 2009. Ascophyllum nodosum (Le Jol.) ecad mackayi (Turn.) Cotton. UK Biodiversity Action Plan, 28pp.

Olsenz, J.L., 2011. Stress ecology in *Fucus*: abiotic, biotic and genetic interactions. *Advances in Marine Biology*, **59** (57), 37.

Phillippi, A., Tran, K. & Perna, A., 2014. Does intertidal canopy removal of *Ascophyllum nodosum* alter the community structure beneath? *Journal of Experimental Marine Biology and Ecology*, **461**, 53-60.

Pinn, E.H. & Rodgers, M., 2005. The influence of visitors on intertidal biodiversity. *Journal of the Marine Biological Association of the United Kingdom*, **85** (02), 263-268.

Rita, A., Isabel, S.-P., Serrao, E.A. & Per, Å., 2012. Recovery after trampling disturbance in a canopy-forming seaweed population. *Marine Biology*, **159** (3), 697-707.

Rohde, S., Hiebenthal, C., Wahl, M., Karez, R. & Bischof, K., 2008. Decreased depth distribution of *Fucus vesiculosus* (Phaeophyceae) in the Western Baltic: effects of light deficiency and epibionts on growth and photosynthesis. *European Journal of*

Phycology, **43** (2), 143-150.

Schonbeck, M. & Norton, T., 1979. Drought-hardening in the upper-shore seaweeds *Fucus spiralis* and *Pelvetia canaliculata*. *Journal of Ecology*, **67**, 687-696.

Sfriso, A., Maistro, S., Andreoli, C. & Moro, I., 2010. First record of *Gracilaria vermiculophylla* (Gracilariales, Rhodophyta) in the po delta lagoons, Mediterranean sea (Italy) 1. *Journal of Phycology*, **46** (5), 1024-1027.

Staehr, P.A., Pedersen, M.F., Thomsen, M.S., Wernberg, T. & Krause-Jensen, D., 2000. Invasion of *Sargassum muticum* in Limfjorden (Denmark) and its possible impact on the indigenous macroalgal community. *Marine Ecology Progress Series*, **207**, 79-88.

Steen, H. & Rueness, J., 2004. Comparison of survival and growth in germlings of six fucoid species (Fucales, Phaeophyceae) at two different temperature and nutrient levels. *Sarsia*, **89**, 175-183.

Strömgren, T., 1977. Short-term effect of temperature upon the growth of intertidal Fucales. *Journal of Experimental Marine Biology and Ecology*, **29**, 181-195.

Thompson, G.A. & Schiel, D.R., 2012. Resistance and facilitation by native algal communities in the invasion success of *Undaria pinnatifida*. *Marine Ecology, Progress Series*, **468**, 95-105.

Thomsen, M., Staehr, P., Nejrup, L. & Schiel, D., 2013. Effects of the invasive macroalgae *Gracilaria vermiculophylla* on two co-occuring foundation species and associated invertebrates. *Aquatic Invasions*, **8** (2), 133-145.

Tyler-Walters, H., 2005b. Assessment of the potential impacts of coasteering on rocky intertidal habitats in Wales. *Report to Cyngor Cefn Gwlad Cymru / Countryside Council for Wales from the Marine Life Information Network (MarLIN).* Marine Biological Association of the United Kingdom, Plymouth, 129 pp.

Weinberger, F., Buchholz, B., Karez, R. & Wahl, M., 2008. The invasive red alga *Gracilaria vermiculophylla* in the Baltic Sea: adaptation to brackish water may compensate for light limitation. *Aquatic Biology*, **3** (3), 251-264.

White, K.L., Kim, J.K. & Garbary, D.J., 2011. Effects of land-based fish farm effluent on the morphology and growth of *Ascophyllum nodosum* (Fucales, Phaeophyceae) in southwestern Nova Scotia. *Algae*, **26** (3), 253-263.