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

Limaria hians beds in tide-swept sublittoral muddy mixed sediment

Dr Harvey Tyler-Walters, Dr Colin Trigg & Frances Perry

2018-02-26

A report from:
The Marine Life Information Network, Marine Biological Association of the United Kingdom.

Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [https://www.marlin.ac.uk/habitats/detail/112]. All terms and the MarESA methodology are outlined on the website (https://www.marlin.ac.uk)
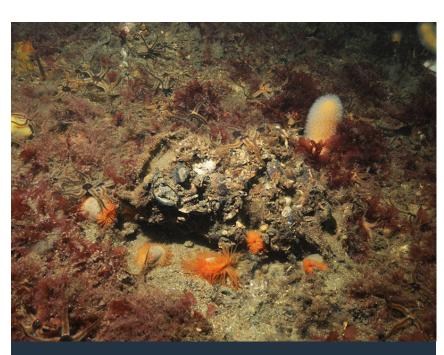
This review can be cited as:
Tyler-Walters, H., Trigg, C. & Perry, F., 2018. [Limaria hians] beds in tide-swept sublittoral muddy mixed sediment. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. DOI https://dx.doi.org/10.17031/marlinhab.112.1
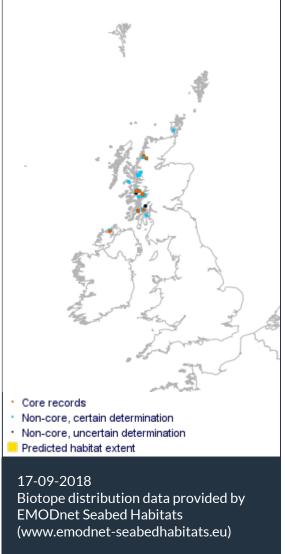
(page left blank)

Limaria hians **beds in tide-swept sublittoral muddy mixed sediment**
Photographer: Keith Hiscock
Copyright: Dr Keith Hiscock

- Core records
- Non-core, certain determination
- Non-core, uncertain determination
- Predicted habitat extent

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

Researched by	Dr Harvey Tyler-Walters, Dr Colin Trigg & Frances Perry	**Refereed by**	Prof. Jason Hall-Spencer

Summary

☰ UK and Ireland classification

EUNIS 2008	A5.434	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment
JNCC 2015	SS.SMx.IMx.Lim	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment
JNCC 2004	SS.SMx.IMx.Lim	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment
1997 Biotope	SS.IMX.FaMx.Lim	*Limaria hians* beds in tide-swept sublittoral muddy mixed sediment

🏷 Description

Mixed muddy gravel and sand often in tide-swept narrows in the entrances or sills of sea lochs with

beds or 'nests' of the flame shell *Limaria hians*. Individuals of *Limaria hians* form woven 'nests' or galleries from byssus and fragments of seaweeds essentially camouflaging themselves. The horse mussel *Modiolus modiolus* sometimes occurs at the same locations, lying amongst the *Limaria hians* bed. Other fauna associated with this biotope include hydroids such as *Kirchenpaueria pinnata*, *Plumularia setacea* and *Nemertesia* spp., mobile crustaceans such as *Cancer pagarus* and *Necora puber* and echinoderms, including *Asterias rubens* and *Ophiothrix fragilis*. Although generally present in water shallower than 30 m depth, beds have been recorded deeper, such as the bed at Loch Sunart which extends to >40 m depth. In shallow enough water, dense algal beds can cover the biogenic habitat, with algae potentially comprising red seaweeds, such as *Phycodrys rubens* and *Plocamium cartilagineum* and kelp such as *Laminaria hyperborea*. (Information adapted from Connor *et al.*, 2004; JNCC, 2105).

↓ Depth range

0-5 m, 10-20 m, 20-30 m, 30-50 m

🏛 Additional information

Little information on the ecology of this biotope was found, and the review presented has been based on the survey data and few detailed studies available (JNCC, 1999; Minchin, 1995, Hall-Spencer & Moore, 2000b, Trigg, 2009; Trigg & Moore, 2009; and Trigg *et al.*, 2011).

✔ Listed By

- none -

⌘ Further information sources

Search on:

G g G JNCC

Habitat review

⟳ Ecology

Ecological and functional relationships

The information below is based on survey data and the few detailed studies available: Gilmour (1967), Minchin (1995), Connor *et al.* (1997), JNCC (1999), and Hall-Spencer & Moore (2000b).

- *Limaria hians* is an active suspension feeder on phytoplankton, bacteria, and detritus.
- The carpet of byssus threads, coarse sediment, and shell produced by *Limaria hians* provides refugia, and substratum for attachment for a wide variety of sessile and sedentary species.
- Other suspension feeders include sponges, hydroids (e.g. *Kirchenpaueria pinnata*, *Nemertesia* spp., and *Tubularia* spp.), bryozoans (e.g. *Bugula* spp.) , soft corals (e.g. *Alcyonium digitatum*), epifaunal and infaunal bivalves (e.g. *Modiolus modiolus* and *Mya truncata* respectively), tube worms (e.g. *Spirobranchus triqueter*), ascidians and small crustaceans. If present, the brittlestars, e.g. *Ophiura* spp. or *Ophiopholis aculeata*, may also suspension feed.
- Kelp (e.g. *Laminaria hyperborea*) and foliose red algae (e.g. *Delesseria sanguinea* or *Phycodrys rubens*) probably provide primary production in the form of detritus and dissolved organic matter, and via grazing by amphipods, isopods, chitons, gastropods (e.g. *Gibbula cineria*, *Tectura virginea* or *Calliostoma zizyphinum*) or sea urchins (e.g. *Psammechinus miliaris*). Suspension feeders, including Limaria hians obtain primary productivity from phytoplankton and benthic and epiphytic microalgae.
- The faunal turf of hydroids and bryozoans is probably grazed by echinoderms (e.g. *Henricia oculata* and *Echinus esculentus*) or gastropods (e.g. *Calliostoma zizyphinum*) or preyed on by polychaetes (e.g. the sea mouse *Aphrodite aculeata*), nudibranchs (e.g. *Onchidoris* sp.) and pycnogonids (e.g. *Achelia echinata*) (Gordon, 1972; Salvini-Plawen, 1972: Ryland, 1976).
- Mobile predators include crabs such as *Cancer pagurus* and *Necora puber*, which probably eat a variety of epifauna including gastropods, small crustacea and bivalves. The nests of *Limaria hians* provide a defence against most predators (Merrill & Turner, 1963: Gilmour, 1967). In addition, *Limaria hians* can also discard its tentacles leaving a predator with a sticky, unpalatable meal while the rest of the animal makes its escape by swimming. The tentacles of *Limaria hians* (especially the longer tentacles) secrete an adhesive and irritant mucus, that has been shown to deter a variety of predators from crabs to fish; e.g. the flounder was reported to spit out *Limaria hians* (Gilchrist, 1896; Merrill & Turner, 1963; Gilmour, 1967). However, the starfish *Asterias rubens* and *Marthasterias glacialis* prey on a wide range of epifauna and molluscs including *Limaria hians* (Minchin, 1995).
- Fish such as juvenile cod *Gadus morhua*, small-spotted catshark (dogfish) *Scyliorhinus canicula*, and dragonets *Callionymus lyra* and gobies probably prey on mobile and sessile epifauna on the bed and may take damaged specimens of *Limaria hians* (JNCC, 1999; Hall-Spencer & Moore, 2000b).
- Starfish, brittlestars, hermit crabs (e.g. *Pagurus bernhardus*), crabs and the common whelk *Buccinum undatum* probably act as epifaunal scavengers within this biotope (JNCC, 1999; Hall-Spencer & Moore, 2000b).
- The nest galleries support a number of detrivores, deposit feeders, scavengers and predators. For example, polychaetes (e.g. *Polynoe* spp. and *Flabelligera affinis*), flatworms and small crustaceans are probably scavengers within the nests, preyed on by polychaetes such as *Glycera lapidum* and *Nephtys hombergi* and ribbon worms) (Hall-Spencer & Moore,

2000b).

Seasonal and longer term change

Seasonal change

In the Plymouth area, *Limaria hians* breeds between early spring to late summer, the larvae present in the water column from August to the following April, with a peak of larval abundance in October at Plymouth or in late summer in Mulroy Bay, Co. Donegal (Lebour, 1937b, MBA, 1957; Allen, 1962; Minchin, 1995).

The macroalgae in the biotope may be expected to show seasonal changes in growth and development; for examples see *Delesseria sanguinea* and *Laminaria hyperborea* reviews. In temperate waters most bryozoan species tend to grow rapidly in spring and reproduce maximally in late summer, depending on temperature, day length and the availability of phytoplankton (Ryland, 1970). Several species of bryozoans and hydroids demonstrate seasonal cycles of growth in spring/summer and regression (die back) in late autumn/winter, overwintering as dormant stages or juvenile stages (see Ryland, 1976; Gili & Hughes, 1995; Hayward & Ryland, 1998). For example, the fronds of *Bugula* species are ephemeral, surviving about 3-4 months but producing two frond generations in summer before dying back in winter, although the holdfasts are probably perennial (Eggleston, 1972a; Dyrynda & Ryland, 1982). The hydroid *Tubularia indivisa* is annual, dying back in winter (Fish & Fish, 1996), while the uprights of *Nemertesia antennina* die back after 4-5 months and exhibit three generations per year (spring, summer and winter) (see reviews; Hughes, 1977; Hayward & Ryland, 1998; Hartnoll, 1998). Many of the bryozoans and hydroid species are opportunists (e.g. *Bugulina flabellata*) adapted to rapid growth and reproduction (*r*-selected), taking advantage of the spring/summer phytoplankton bloom and more favourable (less stormy) conditions (Dyrynda & Ryland, 1982; Gili & Hughes, 1995). Some species such as the ascidians *Ciona intestinalis* and *Clavellina lepadiformis* are effectively annual (Hartnoll, 1998). Therefore, the biotope is likely to demonstrate seasonal changes in the abundance or cover of the epifauna and macroalgae.

Temporal change

Hall-Spencer & Moore (2000b) studied a *Limaria hians* bed over a 5 year period, while Minchin (1995) reported the that *Limaria hians* was abundant in the Moross Channel, Mulroy Bay from 1978-1982 and had been recorded from Mulroy Bay a hundred years previously. This suggests that *Limaria hians* beds, once established, are probably relatively stable unless affected by human impacts or storms (see sensitivity).

Habitat structure and complexity

The gaping file shell *Limaria hians* can build extensive nests made of shell, stones debris and maerl (when present) interlaced by several hundred byssus threads, and lined by mucus, mud and their faeces (Gilchrist, 1896; Hall-Spencer & Moore, 2000b). Nests may be constructed by expansion of smaller burrows, in gravel, shell sand or laminarian holdfasts, or may be simply composed of byssus threads (see Merrill & Turner (1963) and Gilmour (1967) for details). Nests are about the maximum gape of shell in diameter by about twice the length of the animal, with holes for the entrance and exit of water. Nests vary in size and complexity with individual *Limaria hians* being recorded from nests of 2-5 cm diameter, while larger nests of up to 25 cm diameter and 10 cm in length consisted of numerous ventilated holes and galleries (Gilmour, 1967; Tebble, 1976; Hall-Spencer & Moore, 2000b). Hall-Spencer & Moore (2000b) reported that six of these large nests contained 24-52 small and 25-40 large individuals of *Limaria hians*, with adult individuals

occupying single galleries with two ventilation holes, while juveniles occupied complex galleries with multiple ventilation holes. *Limaria hians* can also occur individually or in small numbers, for example in kelp holdfasts, or under stones intertidally (Jason Hall-Spencer, pers com.).

This biotope is characterized by dense populations of *Limaria hians* where the nests coalesce into a carpet or bed over the sedimentary substratum, and in which individual *Limaria hians* are not visible (Connor *et al.*, 1997; JNCC, 1999). For example, in the Creag Gobhainn area of Loch Fyne, *Limaria hians* formed a bed 10-20 cm high, composed of >700 individuals/m2; and covering several hectares (Hall-Spencer & Moore, 2000b) and 216-584 /m2; were reported in the Moross Channel, Mulroy Bay in 1980 (Hobson, 1980 cited in Minchin, 1995). The carpet of nests covers and hence stabilizes the substratum. In addition, the carpet of nests provides substratum for the attachment for a diverse array of sessile and sedentary invertebrates, niches and refugia for mobile epifauna, and the nests themselves support a burrowing infauna and scavengers. The exact composition of the associated community probably varies with location depending on the species present in the surrounding area.

- In shallow examples of this biotope the *Limaria hians* carpet provides substratum for macroalgae, including the kelps *Saccorhiza polyschides*, *Laminaria digitata* and *Saccharina latissima* (studied as *Laminaria saccharina* and their associated flora and fauna (e.g. see EIR.LhypR) , which would otherwise be unable to attach to a sedimentary substratum (Minchin, 1995).
- Sessile epifauna attached to the nests and any available hard substrata such as stones include, sponges (e.g. *Esperiopsis fucorum*), hydroids (e.g. *Kirchenpaueria pinnata*, *Nemertesia* spp., and *Tubularia* spp.), soft corals (e.g. *Alcyonium digitatum*), anemones (e.g. *Urticina felina* and *Metridium dianthus*), bryozoans (e.g. *Bugula* spp.), barnacles (e.g. *Balanus crenatus*), amphipods (e.g. *Ampelisca* spp. and *Jassa* spp.), ascidians (e.g. *Ciona intestinalis* and *Corella parallelogramma*), tube worms (e.g. *Spirobranchus triqueter*), and bivalves (e.g. the horse mussel *Modiolus modiolus* and scallops *Pecten maximus* and *Chlamys varia*) (Connor *et al.*, 1997; JNCC, 1999; Hall-Spencer & Moore, 2000b).
- Mobile epifauna include flatworms, ribbon worms (Nemertea), polychaetes (e.g. the sea mouse *Aphrodite aculeata*), pycnogonids, amphipods, shrimp, hermit crabs (e.g. *Pagurus bernhardus*), crabs (e.g. *Cancer pagurus*, *Hyas araneus*, and *Necora puber*), gastropods (e.g. *Gibbula* spp., *Calliostoma zizyphinum*, and *Buccinum undatum*), nudibranchs (e.g. *Onchidoris* spp.), sea urchins (e.g. *Psammechinus miliaris*), brittlestars (e.g., *Ophiothrix fragilis* and *Ophiocomina nigra*), and starfish (e.g. *Asterias rubens*, *Crossaster papposus* and *Marthasterias glacialis*) (Connor *et al.*, 1997; JNCC, 1999; Hall-Spencer & Moore, 2000b).
- The galleries of the nests also supported scavengers such as scale worms (e.g. *Polynoe* sp.) and predatory polychaetes (e.g. *Lepidonotus squamatus* and *Glycera lapidum*), while the polychaetes *Flabelligera affinis* and the bivalve *Kurtiella bidentata* were associated with the faeces-lined walls of nest galleries (Hall-Spencer & Moore, 2000b).
- Hall-Spencer & Moore (2000b) reported that the sediment underneath the *Limaria hians* bed supported a diverse infaunal community including burrowing bivalves (e.g. *Mya truncata*, *Dosinia exoleta* and *Tapes rhomboides*), the heart urchin *Echinocardium pennatifidum* and the holothurian *Thyonidium drummondi*. The high infaunal biodiversity observed in their study area was attributed to the porosity of the *Limaria hians* beds and the locally strong currents, that allowed adequate exchange of oxygenated water and nutrient. Examples of this biotope that occur in areas of low water movement (i.e. weak currents and wave sheltered conditions) may not exhibit such as diverse community.

Productivity

Little information on productivity was found. However, phytoplankton, benthic microalgae, kelps and other macroalgae probably make an important contribution to primary productivity where abundant. Dame (1996) suggested that dense beds of bivalve suspension feeders increase turnover of nutrients and organic carbon in estuarine (and presumably coastal) environments by effectively transferring pelagic phytoplanktonic primary production to secondary production in the sediments (pelagic-benthic coupling). The *Limaria hians* beds probably also provide secondary productivity in the form of tissue, faeces and pseudofaeces.

Recruitment processes

Limaria hians is dioecious (Ansell, 1974) and can reproduce in its second summer (Minchin, 1995). Hrs-Benko (1973) reported that *Limaria hians* in the northern Adriatic were sexually active throughout the year, with a main spawning period between late spring and summer, while Minchin (1995) noted that settlement normally occurred in August to September in Mulroy Bay. Veligers of *Limaria hians* were collected between August and the following April in the Plymouth area, absent in early summer with a peak in abundance in October (Lebour, 1937b). *Limaria hians* veligers are distinctive and triangular in shape (80-320 μm in length). Larvae reach 320 μm in length within a few weeks in the laboratory, after which metamorphosis occurs, suggesting that the veligers could spend at least a few weeks in the plankton. Newly metamorphosed juveniles grow rapidly, reaching 2 mm in length within about 2.5 months (Lebour, 1937b). Minchin (1995) noted that *Limaria hians* laid down two growth rings per year after their first year, and reported a mean shell length of 2 cm in their third summer. Hrs-Benko (1973) noted that individuals >2.7-3 cm in size died in the Adriatic population, while Minchin (1995) recorded 5 year classes and 6 year old specimens in Mulroy Bay. It is thought that *Limaria hians* may live up to 10 or 11 years; however, growth is very limited after six to seven years (Trigg, 2009). Trigg (2009) suggested there could be variability in the reproductive cycles of *Limaria hians* even within similar geographical locations. Little information is available on the mortality rates of *Limaria hians*. A size-frequency study from a population on the west coast of Scotland, between April 2006 and June 2007, recorded a decline in population density during May in both years (Trigg, 2009). The observed decline could indicate a natural fluctuation within the population when mortality rates are high after spawning (Trigg, 2009).

Limaria hians populations are dependant on recruitment to maintain their abundance as recruitment failure in the Moross Channel, Mulroy Bay , associated with tri-butyl tin (TBT) contamination, resulted in loss of the resident population (Minchin, 1995). This recruitment is in turn dependent on the production of larvae from either the adjacent *Limaria hians* s population or populations within the vicinity of the affected area.

The associated macroalgae, epifauna and interstitial fauna probably depend on locality and recruit from the surrounding area. Many hydroids and most bryozoans, ascidians and probably sponges have short lived plankton or demersal larvae with relatively poor dispersal capabilities. Exceptions include *Nemertesia antennina* and *Alcyonium digitatum* and hydroids that produce medusoid life stages, which probably exhibit relatively good dispersal potential. Hydroids and bryozoans are opportunistic, rapid growing species, with relatively widespread distributions, which colonize rapidly and are often the first groups of species to occur on settlement panels. Sponges and anemones may take longer to recruit to the habitat but are good competitors for space. Recruitment in epifauna communities is discussed in detail in the faunal turf biotopes MCR.Flu, CR.Bug and in *Modiolus modiolus* beds (MCR.ModT).

Mobile epifaunal species, such as echinoderms, crustaceans, and amphipods are fairly vagile and capable of colonizing the community by migration from the surrounding areas, probably attracted by the refugia and niches supplied by the *Limaria hians* carpet. In addition, most echinoderms and crustaceans have long-lived planktonic larvae with high dispersal potential, although, recruitment may be sporadic, especially in echinoderms.

Time for community to reach maturity

The time taken for the biotope to develop would depend on the time required for the *Limaria hians* population to increase in abundance and develop a carpet or bed of byssal nests. Colonization by macroalgae, epifauna, and mobile species would probably be rapid and may enhance development of the byssus carpet (Jason Hall-Spencer pers comm.).

Information on recovery rates is limited and is based largely on observations from Mulroy Bay (Minchin, 1995) and modelled predictions (Trigg & Moore, 2009). The recovery of the *Limaria hians* beds in Moross Channel, Mulroy Bay was studied by Minchin (1995). The population was reduced to only <2% of its 1980 abundance by 1986 (Minchin *et al.*, 1987). In the follow up study, Minchin (1995) reported that after successful spat falls in 1989 onwards, the population, carpet and associated community had returned to their 1980 state by 1994, presumably due to recruitment from a few surviving old specimens or populations in other areas of Mulroy Bay. Trigg & Moore (2009) completely removed a number of small patches of bed material from a *Limaria hians* bed on the west coast of Scotland. They cleared a number of 0.25 m^2 sections within with a bed that represented 100% *Limaria hians* cover. They reported that regrowth generally occurred from peripheral nest material but that recovery within these test patches was not as thick as the undisturbed bed (Trigg & Moore, 2009). Trigg & Moore (2009) estimated that regrowth occurred at a rate of 3.2 cm/annum when the regrowth in the test areas was converted to a linear front. They further estimated that at this rate of regrowth it could take up to 117 years for a *Limaria hians* bed to recover from a 7.5 m dredge running through the habitat, assuming that this dredge completely removed all nest material and *Limaria hians* within the affected area (Trigg & Moore, 2009). However, recent observations from a *Limaria hians* bed in Loch Carron suggest that where the bed is not completely removed by dredging and individual Limaria hians remain, then regrowth may occur more rapidly (Moore, pers. comm).

Additional information

None entered

🖼 Preferences & Distribution

Habitat preferences

Depth Range	0-5 m, 10-20 m, 20-30 m, 30-50 m
Water clarity preferences	Data deficient
Limiting Nutrients	Data deficient
Salinity preferences	Full (30-40 psu), Low (<18 psu), Reduced (18-30 psu), Variable (18-40 psu)
Physiographic preferences	Sea loch / Sea lough

Biological zone preferences	Circalittoral, Infralittoral, Lower circalittoral, Lower infralittoral, Sublittoral, Upper circalittoral
Substratum/habitat preferences	Coarse clean sand, Cobbles, Mixed, Muddy gravel, Muddy gravelly sand, Muddy sand, Muddy sandy gravel, Pebbles
Tidal strength preferences	Moderately Strong 1 to 3 knots (0.5-1.5 m/sec.), Strong 3 to 6 knots (1.5-3 m/sec.), Weak < 1 knot (<0.5 m/sec.)
Wave exposure preferences	Exposed, Extremely sheltered, Moderately exposed, Sheltered, Very sheltered
Other preferences	Data deficient

Additional Information

This biotope has been recorded from 4-98 m on mixed muddy gravel or sand, coarse sands, muddy maerl, and bedrock in areas with weak to strong tidal streams and wave sheltered to extremely wave sheltered habitats (Connor *et al.*, 1997; JNCC, 1999; Hall-Spencer & Moore, 2000b). It is probable that the *Limaria hians* carpet does not occur in shallow depths in wave exposed locations. It occurs at high densities in the Creag Gobhainn area of Loch Fyne (Hall-Spencer & Moore, 2000b) and Moross Channel, Mulroy Bay, Ireland (Minchin, 1995), and is very common in Loch Sunart (Howson, 1996).

🐾 Species composition

Species found especially in this biotope

- *Crossaster papposus*
- *Hyas araneus*
- *Kirchenpauria pinnata*
- *Limaria hians*
- *Nemertesia antennina*
- *Nemertesia ramosa*
- *Ophiocomina nigra*
- *Ophiothrix fragilis*
- *Plumularia setacea*

Rare or scarce species associated with this biotope

-

Additional information

Beds of *Limaria hians* provide stable substrata in otherwise sedimentary habitats and support a diverse epifauna and infauna (Hall-Spencer & Moore, 2000b). The MNCR recorded 324 species within this biotope, although not all species were present in all records of the biotope (Connor et al., 1997a). Hall-Spencer & Moore (2000b) reported 19 species of macroflora and 265 species of invertebrate macrofauna in only six *Limaria hians* nests from one site in Loch Fyne, Scotland. Recently, Trigg *et al.* (2011) recorded 282 species (across 16 phyla) of epiflora, epifauna and infauna, from only two sites in Scotland.

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The biotope is characterized by a dense bed (biogenic reef)of the flame shell *Limaria hians*. Individual *Limaria hians* secrete byssus threads that are attached to surrounding material forming a carpet composed of threads, coarse sediment, shell, and organic matter. This porous layer lies on top of the mixed muddy gravel found within this biotope. Beds of *Limaria hians* provide a stable substratum in otherwise sedimentary habitats and support a diverse epifaunal and infaunal community (Hall-Spencer & Moore, 2000). Many of the species found within the community are characteristic of the wave sheltered and tide swept situations where *Limaria hians* beds are found. The Marine Nature Conservation Review (MNCR) recorded 324 species within this biotope, although not all species were present in all records of the biotope (Connor *et al.*, 1997a). Hall-Spencer & Moore (2000b) recorded more than 280 macrofaunal taxa, of which 19 were algae, in only six *Limaria hians* nests from one site in Loch Fyne, Scotland. A more recent study recorded 227 taxa from a single sampling site, incorporating an area of just 0.08m^2 (Trigg *et al.*, 2011).

Loss or degradation of the *Limaria hians* beds in this biotope would result in reclassification of the sedimentary biotope and the loss or degradation of the associated assemblage, and destabilization of the sediment (Minchin, 1995). Therefore, *Limaria hians* is considered to be the key characterizing and structural species and the sensitivity review focuses on the sensitivity of this species and the beds they create. The sensitivity of other associated species found within this biotope are not given in this assessment as none are thought to be pivotal to the recruitment or maintenance of *Limaria hians* bed. The effect of individual pressures on the other components of the community will be addressed where relevant.

Resilience and recovery rates of habitat

The *Limaria hians* biotope is recorded from the west coast of Scotland, Orkney, and Mulroy Bay, Ireland. It is possible that the highly camouflaged nature of these nests has led to a lack of data regarding their location (Trigg, 2009). In a number of the localities where this biotope has been recorded its extent is decreasing (e.g. Hall-Spencer, 1998; Moore *et al.*, 2013). Wide scale declines of this biotope have been recorded in the Clyde Sea and off the Isle of Man, and it has disappeared from prior strongholds such as the Skelmorlie Bank, Stravanan Bay and Tan Buoy, Great Cumbrae (Hall-Spencer & Moore, 2000b). A report by Moore *et al.* (2013) noted the reduction in extent of a *Limaria hians* bed in Loch Linnhe. Recent communications have confirmed that this bed has deteriorated further since the report was published (Moore, pers.comm). *Limaria hians* is not subject to direct exploitation for either commercial or recreational use. However, *Aequipecten opercularis*, *Pecten maximus* and *Buccinum undatum* are exploited commercially and are associated with SS.SMx.IMx.Lim biotope (Connor *et al.*, 2004).

Natural disturbance of *Limaria hians beds have been* recorded by both Minchin (1995) and Trigg *et al.* (2011). In the strong tidal currents associated with *Limaria hians* beds, kelp holdfasts can tear free from the substratum removing sections of the byssus mat (Minchin, 1995; Hall-Spencer & Moore, 2000; Trigg *et al.*, 2011). It was suggested that these events could lead to a reduction in biodiversity, when compared with the adjacent undisturbed Limaria hians bed, at the point of disturbance (Trigg *et al.*, 2011). After a disturbance event the bed can recover through a combination of nest regrowth by individual *Limaria hians* still present, settlement of juvenile *Limaria hians* and peripheral growth from the edge of the unaffected *Limaria hians* bed, if available (Minchin, 1995; Trigg, 2009; Trigg & Moore, 2009). Therefore, recolonization of the habitat by

associated species can take place. It is also possible that translocation of dislodged, undamaged adults could contribute to recovery (Hall-Spencer & Moore, 2000b).

Juvenile recruitment is probably the most important mechanism for recovery of significantly impacted beds i.e. where individuals of *Limaria hians* have been completely removed from the affected area. This recruitment is in turn dependent on the production of larvae from either the adjacent *Limaria hians* population or populations within the vicinity of the affected area.

Limaria hians is dioecious (Ansell, 1974) and can reproduce in its second summer (Minchin, 1995). It is thought that *Limaria hians* may live up to 10 or 11 years; however, growth is very limited after six to seven years (Trigg, 2009). Within the northern Adriatic, *Limaria hians* are sexually active throughout the year, with a peak in reproduction between late spring and summer (Hrs-Benko, 1973). Minchin (1995) noted that settlement normally occurred in August to September in Mulroy Bay. Veligers of *Limaria hians* were collected between August and the following April in the Plymouth area (Lebour, 1937b). However, Trigg (2009) suggests that there could be variability in the reproductive cycles of *Limaria hians* even within similar geographical locations. Little information is available on the mortality rates of *Limaria hians*. A size-frequency study from a population on the west coast of Scotland, between April 2006 and June 2007, recorded a decline in population density during May in both years (Trigg, 2009). The observed decline could indicate a natural fluctuation within the population when mortality rates are high after spawning (Trigg, 2009).

Information on recovery rates is limited and is based largely on observations from Mulroy Bay (Minchin, 1995) and modelled predictions (Trigg & Moore, 2009). Experiments tracking recovery of deliberately cleared patches also provide some information on recovery from small-scale disturbance. For example, work by Minchin (1995) found that the affected bed in Mulroy Bay fully recovered after nine years following cessation of the antifoulant TBT and an increase in recruitment. Trigg & Moore (2009) completely removed a number of small patches of bed material from a *Limaria hians* bed on the west coast of Scotland. They cleared a number of 0.25 m^2 sections within with a bed that represented 100% *Limaria hians* cover. They reported that regrowth generally occurred from peripheral nest material but that recovery within these test patches was not as thick as the undisturbed bed (Trigg & Moore, 2009). Trigg & Moore (2009) estimated that regrowth occurred at a rate of 3.2 cm/annum when the regrowth in the test areas was converted to a linear front. They further estimated that at this rate of regrowth it could take up to 117 years for a *Limaria hians* bed to recover from a 7.5 m dredge running through the habitat, assuming that this dredge completely removed all nest material and *Limaria hians* within the affected area (Trigg & Moore, 2009). However, recent observations from a *Limaria hians* bed in Loch Carron suggest that where the bed is not completely removed by dredging and individual *Limaria hians* remain, then regrowth may occur more rapidly (Moore, pers. comm).

Resilience assessment. It is considered that the presence of a local healthy population of *Limaria hians* could contribute significantly to the recovery of an impacted bed (e.g. Minchin, 1995; Trigg & Moore, 2009). Recovery rates are, therefore, site-specific and depend on the presence of a source population to allow recolonization. This ability to recruit from a nearby population does not mean that recovery to previous habitat structure is quick, as the study by Trigg & Moore (2009) indicated. Although Minchin (1995) recorded a recovery time of <10 years from a bed reduced to 2% of its original density, Hall-Spencer (pers comm) suggested that this short recovery time may be an exception to a rule. Therefore, where a population of *Limaria hians* experiences some mortality but the habitat is not changed (e.g. Medium resistance), then the habitat has the potential to recover within several years depending on recruitment, a **resilience** of **'Medium'** (2-10

years). Where the population experiences significant mortality, specifically when all individuals of *Limaria hians* have been removed from an affected area, and/or the carpet (bed) is damaged (e.g. resistance is Low or None), then the recovery is likely to be prolonged. In this instance, a **resilience** score of 'Low' (10-25 years) or 'Very Low' (at least 25 years, prolonged or negligible) would be recorded, based on the recovery rates modelled by Trigg & Moore (2009) and the evidence that *Limaria hians* beds are in decline in UK waters.

Note - resilience and the ability of a habitat to recover from human induced pressures is subject to a number of factors. These include, but are not limited to; environmental conditions of the site, the frequency of disturbance events, the intensity of the disturbance and the number of pressures being exerted on a site at any one time. Recovery of impacted populations will always be mediated by stochastic events and processes acting over different scales. Local habitat conditions, further impacts and processes such as larval-supply and recruitment between populations are examples of such scales. 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. It is more important that the relevant functional components are present and the habitat is structurally and functionally recognisable. It should be noted that the recovery rates are only indicative of the recovery potential.

⚓ Hydrological Pressures

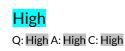|	Resistance	Resilience	Sensitivity
Temperature increase (local)	High Q: Medium A: Low C: NR	High Q: High A: High C: High	Not sensitive Q: Medium A: Low C: Low

Limaria hians has been recorded from the Lofoten Isles in Norway, to as far south as the Canary Isles in the Azores. Therefore, it is unlikely to be affected by long-term changes in temperature at the benchmark level in British waters. Although individual *Limaria hians* have been recorded from the lower shore, the beds are only found in the subtidal and are thus buffered against extreme changes in water temperature. However, it is likely that other species within the community may be affected, for example, Boreal species (e.g. *Balanus crenatus* and *Modiolus modiolus*) may decrease in abundance with an increase in temperature.

Sastry (1966) considered environmental conditions, such as temperature, influential to the reproductive cycle of bivalves. Studies on another member of the Limidae family, *Ctenoides scaber*, found that when water temperature and food abundance increased, gonad size within the organisms studied also increased (Dukeman *et al.*, 2005). Hence, any significant increase in temperature may increase the spawning period of *Limaria hians*. However, as the distribution of *Limaria hians* in the British Isles puts it in the middle of its known geographic range this is unlikely to occur.

Sensitivity assessment. The community composition found on the *Limaria hians* beds may differ with temperature changes. However, the presence of *Limaria hians* is unlikely to change with an increase in temperature at the benchmark level, due to *Limaria hians* being in the middle of its geographic range in the British Isles. Therefore, resistance is assessed as **'High'**, resilience as **'High'** and sensitivity as **'Not sensitive'** at the benchmark level.

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

Limaria hians has been recorded from the Lofoten Isles in Norway, to as far south as the Canary Isles in the Azores. Therefore, it is unlikely to be affected by long-term changes in temperature at the benchmark level in British waters. Although individual *Limaria hians* have been recorded from the lower shore, the beds are only found in the subtidal and are thus buffered against extreme changes in water temperature. However, it is likely that other species within the community may be affected, for example, boreal species (e.g. *Balanus crenatus* and *Modiolus modiolus*) may increase in abundance with a decrease in temperature.

Sastry (1966) considered environmental conditions, such as temperature, influential to the reproductive cycle of bivalves. Studies on another member of the Limidae family, *Ctenoides scaber*, found that when water temperature and food abundance increased, gonad size within the organisms studied also increased (Dukeman *et al.*, 2005). Any significant decrease in temperature may restrict the spawning period of *Limaria hians*. However, as the distribution of *Limaria hians* in the British Isles puts it in the middle of its geographic range this is unlikely to occur.

Sensitivity assessment. The community composition found on the *Limaria hians* beds may differ with temperature changes. However, the presence of *Limaria hians* is unlikely to change with an increase in temperature at the benchmark level, due to *Limaria hians* being in the middle of its range in the British Isles. Therefore, resistance is assessed as **'High'**, resilience as **'High'** and sensitivity as **'Not sensitive'** at the benchmark level.

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

Limaria hians beds are found in fully marine environments. In some locations, such as the shallow sills of sealochs, *Limaria hians* may be exposed to occasional drops in salinity during winter or as a consequence of high rainfall; however, the environment is still considered fully marine.

An increase in salinity at the benchmark level would result in a salinity of >40 psu for one year. Hypersaline water is likely to sink to the seabed and the biotope could be affected by hypersaline effluents (brines). Ruso *et al.* (2007) reported that changes in the community structure of soft sediment communities due to desalinisation plant effluent in Alicante, Spain. In particular, in close vicinity to the effluent, where the salinity reached 39 psu, the community of polychaetes, crustaceans and molluscs was lost and replaced by one dominated by nematodes. Roberts *et al.* (2010b) suggested that hypersaline effluent dispersed quickly but was more of a concern at the seabed and in areas of low energy where widespread alternations in the community of soft sediments were observed. In several studies, echinoderms and ascidians were amongst the most sensitive groups examined (Roberts *et al.*, 2010b).

Sensitivity assessment. Hypersaline effluents are likely to be localised but dispersed quickly in areas of strong currents. Therefore, where the biotope occurs on strong to moderate tidal streams hypersaline effluents may not have an adverse effect. But in areas of weak tidal streams hypersaline effluent could adversely affect the diversity of the biotope and reduce the abundance of *Limaria hians*. Although there is no direct evidence of the effects of hypersaline water on this biotope, hypersaline effluent may cause mortality. Therefore, a resistance of **'Low'** is suggested but at Low confidence. Resilience would probably be **'Low'**, so that sensitivity may be **'High'**.

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

Limaria hians beds are found in fully marine environments. In some locations, such as the shallow sills of sea lochs, *Limaria hians* may be exposed to occasional drops in salinity during winter or as a consequence of high rainfall; however, the environment is still considered fully marine. Therefore, in shallow waters beds may be vulnerable to short-term reductions in salinity; however, these would not be within the benchmark criteria.

Several bivalves have been shown to be able to increase the concentration of free amino acids in their cytoplasm to compensate for decreases in salinity (Berger & Kharazova, 1997). As salinity falls most bivalves close their shells to isolate themselves from the surrounding environment. *Limaria hians* has a gaping shell that cannot be fully closed, and numerous, tentacles that cannot be withdrawn into the mantle cavity. Therefore, although it may exhibit an unknown degree of physiological tolerance, it is unlikely to be able to tolerate reduced or prolonged periods of variable salinity.

Sensitivity assessment. No evidence is available on the impact of a decrease in salinity on *Limaria hians* but the biotope is considered to be fully marine. Consequently, it is not thought that *Limaria hians* would tolerate a decrease in salinity according to the benchmark criteria (i.e. from 'full' to 'reduced' salinity). Therefore, resistance is assessed as **'Low'** and resilience as **'Low'** so that sensitivity may be **'High'.**

Water flow (tidal current) changes (local)	Medium	Medium	Medium
	Q: Low A: NR C: NR	Q: Medium A: Low C: Low	Q: Low A: Low C: Low

This biotope occurs in weak to moderately strong tidal streams (Connor *et al.*, 2004). A change in water flow may affect settlement success of larvae. Studies of both epiphytic and infaunal organisms have found that larvae can settle at a range of flow rates (Abelson *et al.*, 1994; Eckman *et al.*, 1990; Mullineaux & Butman, 1991; Pawlik & Butman, 1993). It is likely that larvae use different flow rates as physical cues as to whether they have settled in the correct habitat (Abelson & Denny, 1997). To date, there is no information on how *Limaria hians* larvae respond to changes in water flow rate. However, significant changes in water flow rate could determine the success of larval settlement.

Limaria hians feeds on suspended organic matter such as microalgae, phytoplankton, bacteria and detritus (Trigg, 2009). As an active suspension feeder water is diverted into the mantle cavity of the organism, and then over its gill filaments (Ward *et al.*, 2004). Changes in flow rate would, therefore, affect the amount of suspended particulate matter passing the organism within the water column. Investigations into the effects of water flow velocity on scallops have found that flow rates can affect growth (Cahalan *et al.*, 1989; Eckman, 1987; Wildish *et al.*, 1987). No specific information is available on water flow and growth rates for *Limaria hians*. A reduction in flow rate would also lead to lighter sediment particles falling out of suspension, increasing siltation on the *Limaria hians* bed (see siltation). Reduced water flow would also reduce the availability of oxygen to the organism (see deoxygenation), and reduce removal of faeces generated by *Limaria hians* and other organisms residing in the nest material

If water flow was to increase from strong (1.5-3 m/s) to very strong (> 3 m/s) it is possible that physical damage to the bed could occur. The additional drag caused by epibiota attached to the carpet, particularly kelp, could result in removal of patches as the kelp is torn from the bed. Holes in the carpet may then lead to remobilization of the sediment, resulting in further damage (Minchin, 1995) and leaving coarser sediment fractions. However, water flow is important for the oxygen and nutrient exchange within the byssus carpet, the removal of waste products, the supply

of food to the dominant suspension feeders (inc. *Limaria hians*) and to keep the byssus carpet clear of sediment that may otherwise clog the carpet. Therefore, a reduction in flow is likely to be detrimental to the survival and diversity of the *Limaria hians* beds, especially in areas that lack wave-induced water flow. For example, Hall-Spencer & Moore (2000b) reported that the sediment underneath the *Limaria hians* bed supported a diverse infaunal community including burrowing bivalves (e.g. *Mya truncata*, *Dosinia exoleta* and *Polititapes rhomboides*), the heart urchin *Echinocardium pennatifidum* and the holothurian *Thyonidium drummondi*. The high infaunal biodiversity observed in their study area was attributed to the porosity of the *Limaria hians* beds and the locally strong currents, that allowed adequate exchange of oxygenated water and nutrient. Examples of this biotope that occur in areas of low water movement (i.e. weak currents and wave sheltered conditions) may not exhibit such as diverse community.

Sensitivity assessment. A significant increase in water flow rate may physically disturb the bed, particularly where examples of the feature inhabit areas already at the upper tolerance limit to flow rates but an increase in water flow of 0.1-0.2 m/s, is unlikely to adversely affect the biotope. However, a significant decrease in water flow is likely to be detrimental. Therefore, a precautionary resistance of **'Medium'** is recorded (at the benchmark level) to represent possible damage and loss of diversity. Hence, resilience is assessed as **'Medium'** and sensitivity as '**Medium'**.

Emergence regime 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

Individual *Limaria hians* have been recorded from the low water mark. However the SS.SMx.IMx.Lim biotope is only found subtidally (Connor *et al.*, 2004) from approximately 5 m to 40 m. Therefore, as the beds are found in fully subtidal areas this pressure is considered 'Not relevant'.

Wave exposure changes (local)	Medium	Medium	Medium
	Q: Low A: NR C: NR	Q: Medium A: Medium C: Medium	Q: Low A: Low C: Low

This biotope is associated extremely wave sheltered to wave sheltered environments (Connor *et al.*, 2004). Even a small increase in significant wave height has the potential to damage shallow examples of the biotope if this increase would lead to a wave 'exposed' environment. The oscillatory nature of wave induced water movement is potentially damaging, especially where foliose macroalgae (e.g. kelps) attached to the carpet increase drag. An increase in wave exposure from sheltered to exposed may result in disruption of the byssal carpet and mobilization of the substratum, especially where the biotope is found in shallower water. Conversely, a decrease in wave exposure would not be considered to affect the community if flow rates were not significantly affected.

Sensitivity assessment. This is a wave sheltered biotope so that even a small increase in significant wave height has the potential to damage shallow examples of the biotope if this increase would lead to a wave exposed environment. However, a 3-5% change in significant wave height is only likely to affect sheltered examples of the biotope in their most shallow extent. Conversely, a decrease in wave exposure would not be considered to affect the community provided that flow rates were not significantly affected. Therefore, a precautionary resistance of **'Medium'** is recorded to represent possible damage to the most shallow extent of the biotope in already wave sheltered localities. Hence, resilience is assessed as **'Medium'** and sensitivity as '**Medium'**.

⚗ 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.

In the Moross Channel, Mulroy Bay, an intensive settlement of *Limaria hians* spat occurred in 1982 followed by five years of failed settlement, which coincided with the use of TBT in fish farms in the area. *Limaria hians* samples in 1985 contained 0.2 µg/g tri-butyl tin oxide and similar levels were found in the Pacific oyster, scallops and mussels in the same area.*Limaria hians* larvae were detected again after the use of TBT was discontinued in 1985 (Minchin *et al.*, 1987; Minchin, 1995). Minchin (1995) suggested that TBT contamination was the most likely cause of the disappearance of larvae from the plankton. *Mytilus edulis* continued to settle during the impacted period suggesting that *Limaria hians* was more intolerant.

Limaria hians populations are dependent on recruitment to maintain their abundance. A recruitment failure in Mulroy Bay associated with tri-butyl tin (TBT) contamination, resulted in loss 98% of the population between 1980 and 1986. Minchin (1995) studied the recovery of this population of *Limaria hians* and found that once recruitment began again in 1989, recovery was rapid so that by 1994 the population and an extensive carpet of byssal nests indicated recovery to the earlier 1980 state. Young saithe were again present sheltering in a re-established kelp cover, suggesting that the community as a whole had also recovered. This suggests that where individuals survive and in the presence of good recruitment, a population may be able to regain its prior abundance within five years.

Minchin (1995) noted that good recruitment was necessary to maintain the byssal carpet. Poor recruitment resulted in a weakening of the byssal carpet, which was pulled away in tufts due to drag by kelps in the strong currents, mobilization of the sediment and resultant smothering, and loss of the carpet, its attached kelps and associated community and the population was reduced to 1.6% of its 1980 abundance.

If TBT inhibits the settlement of *Limaria hians* larvae then it is accurate to give a resistance of 'None'. The fast recovery recorded by Minchin (1995) suggests that if TBT use is restricted then *Limaria hians* can recover. However, it is not clear if the speed of recovery seen in Mulroy Bay would occur everywhere.

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.

Subtidal populations are protected from the direct effects of oil spills by their depth but are likely to be exposed to the water soluble fraction of oils and hydrocarbons, or hydrocarbons adsorbed onto particulates.

Suchanek (1993) noted that sub-lethal levels of oil or oil fractions reduce feeding rates, reduce respiration and hence growth, and may disrupt gametogenesis in bivalve molluscs. Widdows *et*

al.(1995) noted that the accumulation of PAHs contributed to a reduced scope for growth in *Mytilus edulis*. However, no information on the responses of *Limaria hians* to hydrocarbons was found.

Laboratory studies of the effects of oil and dispersants on several red algae species, including *Delesseria sanguinea* (Grandy, 1984 cited in Holt *et al.*, 1995) concluded that they were all sensitive to oil/ dispersant mixtures, with little differences between adults, sporelings, diploid or haploid life stages. O'Brien & Dixon (1976) suggested that red algae were the most sensitive group of algae to oil or dispersant contamination.

Synthetic compound contamination	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

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

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

Sensitivity assessment. There is 'No Evidence' available for the effect of this pressure on *Limaria hians.*

Introduction of other substances	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

This pressure is **Not assessed**.

De-oxygenation	No evidence (NEv)	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 information on the tolerance of hypoxia by *Limaria hians* was found. However, as *Limaria hians* beds tend to be found in areas subjected to moderate water flow it may suggest that this organism requires well oxygenated water. Nevertheless, there is 'No evidence' available for the effect of this pressure on *Limaria hians* beds.

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

This pressure relates to increased levels of nitrogen, phosphorus and silicon in the marine environment compared to background concentrations. Moderate increases in nutrient levels may benefit *Limaria hians* by increasing macroalgal and phytoplankton productivity. In turn, these factors would increase the supply of materials used to bind into byssal nests and increase the food supply. Similarly, increased availability of organic particulates may benefit the other suspension feeding members of the community, e.g. hydroids, bryozoans, sponges and ascidians.

Conversely, nutrient enrichment could lead to increased turbidity (see 'changes in suspended solids') and decreased oxygen levels due to bacterial decomposition of organic material (see 'deoxygenation'). However, Shumway (1990) reported the toxic effects of algal blooms on

commercially important bivalves. This would suggest that prolonged or acute nutrient enrichment may have adverse effects on suspension feeding bivalves such as *Limaria hians*. A bloom of the toxic flagellate *Chrysochromulina polypedis* in the Skagerrak resulted in death or damage of numerous benthic animals, depending on depth.

Sensitivity assessment. The benchmark is set at compliance with WFD criteria for good status, based on nitrogen concentration (UKTAG, 2014). Therefore, the biotope is considered to be 'Not sensitive' at the pressure benchmark that assumes compliance with good status as defined by the WFD.

Organic enrichment	No evidence (NEv)	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 empirical evidence was found to support the sensitivity assessment of *Limaria hians* and its beds to organic enrichment. Therefore, 'No evidence' has been recorded.

⚔ Physical Pressures

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

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

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

Limaria hians beds are only recorded from sedimentary habitats. A permanent change from soft (sediment) to a hard (rock, or artificial) substratum will result in loss of the biotope. Therefore, the habitat is considered to have a resistance of 'None' to this pressure and to be unable to recover from a permanent change of substratum, so that resilience is 'Very Low'. Sensitivity within the direct spatial footprint of this pressure is, therefore 'High'. Although no specific evidence is described confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

Physical change (to another sediment type)	Medium	Very Low	Medium
	Q: High A: Medium C: Medium	Q: Medium A: Medium C: Medium	Q: High A: Medium C: Medium

The *Limaria hians* biotope is found on mixed muddy, sandy gravel (Connor *et al.*, 2004). Trigg *et al.* (2011) commented that any one *Limaria hians* bed can cover a range of sediment types. Sedimentary particles are bound up in the byssus nests created by these bivalves and contribute to

their camouflage. The ability of *Limaria hians* to bind different sediment types into their byssus threads suggests that a change in the sediment composition may not decrease their ability to bind substrata. Although not proven with *Limaria hians* beds, other complex bivalve reefs have been shown to slow down water flow (Crooks & Khim, 1999), leading to the deposition of fine sediments within the reef. This process would mean that well established *Limaria hians* beds could change the sediment composition themselves and become muddier over time.

If the sediment composition changes it's likely that the biodiversity of the area would decrease. Trigg *et al.* (2011) found that there was high infaunal polychaete diversity within the different sediment types. Consequently, if you were to lose one of these sediment types you would lose a niche and its associated fauna.

Sensitivity assessment. The impact of the underlying sediment becoming either finer or coarser is not clear and there is also a possibility that the presence of the *Limaria hians* bed could over time change the substratum composition by decreasing the speed of water flow. A resistance of **'Medium'** is given to represent the change in the associated infaunal community (e.g. from a coarse sediment community to a fine sediment community). The pressure represents a permanent change so that resilience is **'Very low'**. Therefore, sensitivity is assessed as **'Medium'**.

Habitat structure changes - removal of substratum (extraction)	None	Very Low	High
	Q: Medium A: Medium C: NR	Q: Medium A: Medium C: Medium	Q: Medium A: Medium C: Low

Removal of the substratum would result in removal of the *Limaria hians* byssal carpet and the associated community (see abrasion/disturbance).

Sensitivity assessment. A resistance of **'None'** has been given. If the substratum is removed then the overlying byssal nest would also be removed. Resilience would depend on the extent of substratum removal. Even if a small amount of substratum was removed, based on Trigg & Moores (2009) predictions for recovery within a healthy bed, it could take decades for the bed to recover fully. Therefore, resilience has been assessed as '**Very Low',** and overall sensitivity as **'High'.**

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

Evidence suggests that anthropogenic pressures have led to decreases in the abundance of *Limaria. hians* throughout the UK, most significantly in the second half of the 20th century (Trigg, 2009; Gilmour, 1967; Ansell, 1974; Tebble, 1974; Seaward, 1990; Hall-Spencer & Moore, 2000b). Hall-Spencer & Moore (2000b) concluded that *Limaria hians* beds were intolerant to physical disturbance by mooring chains, hydraulic dredges or towed demersal fishing gear. Hall-Spencer & Moore (2000b) reported that a single pass of a scallop dredge at Creag Gobhainn, Loch Fyne ripped apart and mostly removed the *Limaria hians* bed. Damaged file shells were consumed by scavengers (e.g. juvenile cod *Gadus morhua*, whelks *Buccinum undatum,* hermit crabs *Pagurus bernhardus* and other crabs) within 24 hrs. Hall-Spencer & Moore (2000b) noted that although *Limaria hians* were able to swim, the shell was thin and likely to be damaged by mechanical impact. Damage to the *Limaria hians* carpet would result in the exposure of the underlying sediment and exacerbate the damage resulting in the marked loss of associated species (Hall-Spencer & Moore, 2000b).

Trigg & Moore (2009) simulated a scallop dredge event on the extensive *Limaria hians* bed off Port Appin on the west coast of Scotland. They cleared 0.25 m^2 sections within an area of habitat with 100% *Limaria hians* cover. They reported that re-growth generally occurred from peripheral nest material but that recovery within these test patches was not as thick as the undisturbed bed (Trigg & Moore, 2009). Trigg & Moore (2009) estimated that regrowth occurred at a rate of 3.2 cm/annum when the regrowth in the test areas was converted to a linear front. However, this prediction does not allow for the effect of any other pressures or the return of the bed to maximum density.

Species with fragile tests such as *Echinus esculentus* and the brittlestar *Ophiocomina nigra* are reported to suffer badly from the impact of a passing scallop dredge (Bradshaw *et al.*, 2000). Scavenging species would probably benefit in the short-term, while epifauna would be removed or damaged with the byssal carpet.

Sensitivity assessment. A resistance of **'None'** has been recorded. Resilience to such pressures are **'Very low'** and the overall sensitivity assessment is **'High'.**

Penetration or disturbance of the substratum subsurface	None	Very Low	High
	Q: High A: High C: High	Q: High A: Medium C: Medium	Q: Medium A: Medium C: High

Penetration and or disturbance of the substratum would result in similar, if not identical results as abrasion or removal of the *Limaria hians* byssal carpet and the associated community (see abrasion/disturbance).

Sensitivity assessment. A resistance of 'None' has been given. If the substratum is removed then the overlying byssal nest would also be removed. Even if a small amount of substratum was removed, based on Trigg & Moores' (2009) predictions for recovery within a healthy reef, it could take decades for the bed to recover fully. Therefore, resistance is ranked 'None', resilience has been assessed as 'Very Low' resulting in sensitivity being 'High'.

Changes in suspended solids (water clarity)	Medium	Medium	Medium
	Q: Low A: Low C: Low	Q: Medium A: Medium C: Medium	Q: Low A: Low C: Low

An increase in suspended sediment levels may adversely affect suspension feeding species by clogging feeding and respiratory structures and may result in increased siltation depending on water movement. Minchin (1995) suggested that *Limaria hians* was common in areas free of silt and mud. However, *Limaria hians* beds have been recorded on muddy sand and gravel in wave sheltered areas with weak tidal streams such as lochs, and presumably are subject to suspended sediment and siltation.

Limaria hians beds are probably reasonably tolerant to changes in suspended sediment and siltation regimes. However, an increase in suspended sediment loads is likely to reduce feeding efficiency of suspension feeders including *Limaria hians* and increase energetic costs in the form of sediment rejection currents, mucus and pseudofaeces in the *Limaria hians*.

Sensitivity assessment. Overall, a resistance of **'Medium'** has been recorded with a resilience of **'Medium',** giving a sensitivity score of **'Medium'**

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

Minchin (1995) reported that degradation of the *Limaria hians* bed resulted in patches of exposed shell-sand. As the underlying substratum became exposed it became mobile and subsequently began to bury some of the surviving *Limaria hians*, which contributed to the decline of the bed. Smothering by 5 cm of sediment is likely to prevent water flow through the byssal nests of *Limaria hians*, preventing feeding, and resulting in local hypoxia.

Interstitial or infaunal species are unlikely to be adversely affected, although feeding may be interrupted and mobile species will avoid the effects. Small epifaunal species, who require water flow for gaseous exchange and feeding are likely to be killed by a large deposition of sediment. Some larger species may not be entirely smothered and continue growing. However, it should be acknowledged that deposition of fine material in areas consistently subjected to moderate tidal streams is likely to result in remobilisation of the fine sediment. Therefore, any chronic effects of deposition are likely to be highly temporary. Consequently, resistance would likely be higher than expected, due to removal and dispersion of the fine material within a tidal cycle.

Sensitivity assessment. The deposition of fine sediment, as a single event, could cause the loss of a proportion of the gaping file shell population and resultant degradation of the byssal carpet and loss of some associated epifauna and, hence, species richness. However, in areas of strong to moderately strong water flow, any deposit is likely to be removed rapidly and resistance would be 'High'. But in areas of weak water flow or sheltered from water flow and wave action, the deposit may adversely affect a proportion of the bed. Therefore, resistance is assessed as **'Medium'**, resilience as **'Medium'**, and sensitivity assessed as **'Medium'** against light deposition of fine sediments.

Smothering and siltation rate changes (heavy)	None	Very Low	High
	Q: Low A: NR C: NR	Q: Medium A: Medium C: Medium	Q: Low A: Low C: Low

The deposition of 30 cm of fine sediment on a *Limaria hians* bed is likely to have more severe consequences than the deposition on 5 cm of similar sediment (see above). Remobilisation of 30 cm of fine material is unlikely to occur within the same timeframes as for light deposition. Should the material remain then it is assumed that all *Limaria hians* and many of the associated community would die of hypoxia. It could also be assumed that all but the largest epiphytes would also be affected by the inability to undergo gaseous exchange, photosynthesise or feed. This would remove many of the species within the biotope, leading to a loss of ecosystem function.

Sensitivity assessment. Therefore, resistance is assessed as **'None'**, resilience as '**Very low'** and sensitivity as **'High'.**

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

Electromagnetic changes	No evidence (NEv)	No evidence (NEv)	No evidence (NEv)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

Sensitivity assessment. There is 'No Evidence' available for the effect of this pressure on *Limaria hians.*

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

No evidence was found as to whether *Limaria hians* can perceive sound, or whether this could cause negative stress to the animal. Some members of the community may respond to vibrations caused by sound and withdraw and temporarily stop feeding but otherwise, the effects of noise are probably Not relevant.

Introduction of light or shading	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

Sensitivity assessment. In this biotope, *Limaria hians* lives with a byssus nest and is unlikely to be exposed to changes in light levels. An increase in light levels at the benchmark is unlikely to influence photosynthesis in macroalgae, expect in the shallowest habitats, and even then a change of 0.1 lux is unlikely to be significant. Changes in the duration of illumination may affect spawning in species that use moonlight or day length as cues but no evidence of this effect was found. Therefore, the effects of this pressure are considered 'Not relevant'.

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

Sensitivity assessment. This pressure is only applicable to mobile species such as fish and marine mammals, and not seabed habitats. Physical and hydrographic barriers may limit the dispersal of seed. But seed dispersal is not considered under the pressure definition and benchmark. Consequently, the effect of this pressure on *Limaria hians* has been considered 'Not Relevant'.

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

Sensitivity assessment. 'Not Relevant' for benthic habitats. Collision by grounding vessels is addressed under the 'surface abrasion' pressure.

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

Sensitivity assessment. In this biotope, *Limaria hians* lives with a byssus nest and is unlikely to be exposed to visual disturbance. Therefore, the effects of this pressure are considered 'Not relevant'.

🐌 Biological Pressures

	Resistance	Resilience	Sensitivity

Genetic modification & translocation of indigenous species	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

Key characterizing species within this biotope are not cultivated or translocated. Translocation has the potential to transport pathogens or non-native species to uninfected areas (see pressures 'introduction of microbial pathogens' and 'introduction or spread of invasive non-native species'). The sensitivity of the 'donor' population to harvesting to supply stock for translocation is assessed for the pressure 'removal of non-target species'. Therefore, this pressure is 'Not relevant' to *Limaria hians* beds.

Introduction or spread of invasive non-indigenous species	No evidence (NEv)	No evidence (NEv)	No evidence (NEv)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

Sensitivity assessment. There is 'No evidence' available for the effect of this pressure on *Limaria hians.*

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

Limaria hians may be infested with 'oyster gill worms', trematodes of the genus *Urastoma* but they are considered to be harmless facultative commensals (Lauckner, 1983). *Limaria hians* may also act as secondary hosts for the metacercariae of digenean trematodes, which may cause sublethal effects or in extreme cases parasitic castration (Lauckner, 1983).

Sensitivity assessment. Although infected individuals may not recover from the sublethal effects of trematodes, the relatively short lifespan of *Limaria hians* may allow the population to recover rapidly. However, in the absence of evidence of mortality due to diseases or pathogens, a resistance of **'High'** is recorded. Therefore, resilience is assessed as **High'** and sensitivity as **'Not sensitive'.**

Removal of target species	High	High	Not sensitive
	Q: Medium A: Medium C: Medium	Q: High A: High C: High	Q: Medium A: Medium C: Medium

Exploitation of other species in the vicinity of *Limaria hians* beds is likely to be responsible for a significant decline in *Limaria hians* (Hall-Spencer, 1998, 1999, Hall-Spencer & Moore, 2000, A. Brand pers comm. taken from Hall-Spencer & Moore, 2000b, Wood, 1988). Lobsters and crabs are targeted by potting on the Loch Fyne *Limaria hians* beds, although no evidence of damage to the *Limaria hians* has been seen in this area (Hall-Spencer, pers comm.).

The scallop species *Aequipecten opercularis* and *Pecten maximus,* as well as the whelk *Buccinum undatum,* are species which are associated with *Limaria hians* beds as well as being commercially exploited species within the UK. The static or mobile gears that are used to target these species can cause direct physical impact. These impacts are assessed through the abrasion and penetration of the seabed pressures. *Aequipecten opercularis* is recorded as occasional, *Pecten maximus* is recorded as rare and *Buccinum undatum* is recorded as occasional within SS.SMx.IMx.Lim (Connor *et al.,* 2004).

However, the removal of the above species from the biotope may not have a significant negative impact on the community. While removal of this target species will reduce species richness there is no known obligate relationship between these species and, therefore, the loss of species is unlikely to adversely affect the resident *Limaria hians* population.

Sensitivity assessment. Therefore, a 'High' resistance and resilience to this pressure is suggested and sensitivity is ranked 'Not Sensitive'.

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

SS.SMx.IMx.Lim may be directly removed or damaged by static or mobile gears that are targeting other species. Scallop dredging and other invasive forms of fishing have been reported to have decimated the previously extensive *Limaria hians* beds in the Clyde (Wood, 1988, Hall-Spencer, 1998, Hall-Spencer & Moore, 2000a, 2000b; Trigg & Moore, 2009). These direct, physical impacts are assessed through the abrasion and penetration of the seabed pressures. The accidental removal of *Limaria hians* would be highly detrimental to the biotope as the biotope is characterized by this species.

Sensitivity assessment. The resistance of *Limaria hians* to accidental removal is **'None'**. The resilience of the species would depend on the extent of removal. A resilience score of **'Very low'** has been given in light of the recovery times predicted by Trigg & Moore (2009). This results in a sensitivity score of **'High'.**

Bibliography

Abelson, A. & Denny, M., 1997. Settlement of marine organisms in flow. *Annual Review of Ecology and Systematics*, **28:** 317-339.

Abelson, A., Weihs, D. & Loya, Y., 1994. Hydrodynamic impediments to settlement of marine propagules, and adhesive-filament solutions. *Limnology and Oceanography*, **39**, 164-169.

Allen, J.A. 1962. *The fauna of the Clyde Sea area. Mollusca.* Millport: Scottish Marine Biological Association.

Ansell, A.D., 1974. Seasonal change in biochemical composition of the bivalve *Lima hians* from the Clyde Sea area. *Marine Biology*, **27**, 115-122.

Berger, V.J. & Kharazova, A., 1997. Mechanisms of salinity adaptations in marine molluscs. *Interactions and Adaptation Strategies of Marine Organisms*: Springer, pp. 115-126.

Boolootian, R.A.,1966. *Physiology of Echinodermata.* (Ed. R.A. Boolootian), pp. 822-822. New York: John Wiley & Sons.

Bradshaw, C., Veale, L.O., Hill, A.S. & Brand, A.R., 2000. The effects of scallop dredging on gravelly seabed communities. In: *Effects of fishing on non-target species and habitats* (ed. M.J. Kaiser & de S.J. Groot), pp. 83-104. Oxford: Blackwell Science.

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.

Bryan, G.W., 1984. Pollution due to heavy metals and their compounds. In *Marine Ecology: A Comprehensive, Integrated Treatise on Life in the Oceans and Coastal Waters*, vol. 5. *Ocean Management*, part 3, (ed. O. Kinne), pp.1289-1431. New York: John Wiley & Sons.

Cahalan, J.A., Siddall, S.E. & Luckenbach, M.W., 1989. Effects of flow velocity, food concentration and particle flux on growth rates of juvenile bay scallops *Argopecten irradians. Journal of Experimental Marine Biology and Ecology*, **129** (1), 45-60.

Connor, D., Allen, J., Golding, N., Howell, K., Lieberknecht, L., Northen, K. & Reker, J., 2004. The Marine Habitat Classification for Britain and Ireland Version 04.05 JNCC, Peterborough. ISBN 1 861 07561 8.

Connor, D.W., Dalkin, M.J., Hill, T.O., Holt, R.H.F. & Sanderson, W.G., 1997a. Marine biotope classification for Britain and Ireland. Vol. 2. Sublittoral biotopes. *Joint Nature Conservation Committee, Peterborough, JNCC Report* no. 230, Version 97.06., *Joint Nature Conservation Committee, Peterborough, JNCC* Report no. 230, Version 97.06.

Crimaldi, J.P., Thompson, J.K., Rosman, J.H., Lowe, R.J. & Koseff, J.R., 2002. Hydrodynamics of larval settlement: The influence of turbulent stress events at potential recruitment sites. *Limnology and Oceanography*, **47** (4), 1137-1151.

Crompton, T.R., 1997. *Toxicants in the aqueous ecosystem.* New York: John Wiley & Sons.

Crooks, J.A. & Khim, H.S., 1999. Architectural vs. biological effects of a habitat-altering, exotic mussel, *Musculista senhousia. Journal of Experimental Marine Biology and Ecology*, **240** (1), 53-75.

Dame, R.F.D., 1996. *Ecology of Marine Bivalves: an Ecosystem Approach.* New York: CRC Press Inc. [Marine Science Series.]

Davies, C.E. & Moss, D., 1998. European Union Nature Information System (EUNIS) Habitat Classification. *Report to European Topic Centre on Nature Conservation from the Institute of Terrestrial Ecology, Monks Wood, Cambridgeshire.* [Final draft with further revisions to marine habitats.], Brussels: European Environment Agency.

Dukeman, A.K., Blake, N.J. & Arnold, W.S., 2005. The reproductive cycle of the flame scallop, *Ctenoides scaber* (Born 1778), from the lower Florida Keys and its relationship with environmental conditions. *Journal of Shellfish Research*, **24** (2), 341-351.

Dyrynda, P.E.J. & Ryland, J.S., 1982. Reproductive strategies and life histories in the cheilostome marine bryozoans *Chartella papyracea* and *Bugula flabellata. Marine Biology*, **71**, 241-256.

Eckman J.E., 1987. The role of hydrodynamics in recruitment, growth, and survival of *Argopecten irradians* (L.) and *Anomia simplex* (D'Orbigny) within eelgrass meadows. *Journal of Experimental Marine Biology and Ecology*, 106 (2), 165-191.

Eckman, J.E., 1990. A model of passive settlement by planktonic larvae onto bottoms of differing roughness. *Limnology and Oceanography*, **35** (4), 887-901.

Eggleston, D., 1972a. Patterns of reproduction in marine Ectoprocta off the Isle of Man. *Journal of Natural History*, **6**, 31-38.

Fish, J.D. & Fish, S., 1996. *A student's guide to the seashore.* Cambridge: Cambridge University Press.

Göransson, P., Karlsson, M., 1998. Knähagen Reef - Pride of the Öresund. A 100 Year Perspective of Biological Diversity in a Marine Coastal Area. Helsingborg. Report to the *Malmöhus County Board and the Environmental Agency of Helsingborg City*,

Gilchrist, J.D.F., 1896. *Lima hians* and its mode of life. *Transactions of the Natural History Society of Glasgow*, **4**, 218-225.

Gili, J-M. & Hughes, R.G., 1995. The ecology of marine benthic hydroids. *Oceanography and Marine Biology: an Annual Review*, **33**, 351-426.

Gilmour, T.H.J., 1967. The defensive adaptations of *Lima hians* (Mollusca, Bivalvia). *Journal of the Marine Biological Association of the United Kingdom*, **47**, 209-221.

Gordon, D.P., 1972. Biological relationships of an intertidal bryozoan population. *Journal of Natural History*, **6**, 503-514.

Hall-Spencer, J., 1999. Maerl habitats under threat. *Marine Conservation*, **4**, 15.

Hall-Spencer, J.M. & Moore, P.G., 2000a. Impact of scallop dredging on maerl grounds. In *Effects of fishing on non-target species and habitats.* (ed. M.J. Kaiser & S.J., de Groot) 105-117. Oxford: Blackwell Science.

Hall-Spencer, J.M. & Moore, P.G., 2000b. *Limaria hians* (Mollusca: Limacea): A neglected reef-forming keystone species. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **10**, 267-278.

Hall-Spencer, J.M., 1998. Conservation issues relating to maerl beds as habitats for molluscs. *Journal of Conchology Special Publication*, **2**, 271-286.

Hartnoll, R.G., 1998. Circalittoral faunal turf biotopes: an overview of dynamics and sensitivity characteristics for conservation management of marine SACs, Volume VIII. *Scottish Association of Marine Sciences, Oban, Scotland.* [UK Marine SAC Project. Natura 2000 reports.]

Hayward, P.J. & Ryland, J.S. 1998. *Cheilostomatous Bryozoa. Part 1. Aeteoidea - Cribrilinoidea.* Shrewsbury: Field Studies Council. [Synopses of the British Fauna, no. 10. (2nd edition)]

Hiscock, K., 1983. Water movement. In *Sublittoral ecology. The ecology of shallow sublittoral benthos* (ed. R. Earll & D.G. Erwin), pp. 58-96. Oxford: Clarendon Press.

Holt, T.J., Jones, D.R., Hawkins, S.J. & Hartnoll, R.G., 1995. The sensitivity of marine communities to man induced change - a scoping report. *Countryside Council for Wales, Bangor, Contract Science Report*, no. 65.

Holt, T.J., Rees, E.I., Hawkins, S.J. & Seed, R., 1998. Biogenic reefs (Volume IX). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs. *Scottish Association for Marine Science (UK Marine SACs Project)*, 174 pp.

Howson, C.M., 1996. Survey of the shallow sublittoral biotopes in Loch Sunart. *Scottish Natural Heritage Research, Survey and Monitoring Report*, no. 67.

Hrs-Benko, M., 1973. Notes on the biology of *Lima hians* in the north Adriatic Sea. *Rapports et Proces-verbaux des Reunions. Commission Internationale pour l'Exploration Scientifique de la Mer Mediterranee. Paris*, **21**(9), 697-699.

Hughes, R.G., 1977. Aspects of the biology and life-history of *Nemertesia antennina* (L.) (Hydrozoa: Plumulariidae). *Journal of the Marine Biological Association of the United Kingdom*, **57**, 641-657.

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

JNCC (Joint Nature Conservation Committee), 1999. *Marine Environment Resource Mapping And Information Database (MERMAID): Marine Nature Conservation Review Survey Database.* [on-line] http://www.jncc.gov.uk/mermaid

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.

Lauckner, G., 1983. Diseases of Mollusca: Bivalvia. In *Diseases of marine animals.* Vol. II. *Introduction, Bivalvia to Scaphopoda* (ed. O. Kinne), pp. 477-961. Hamburg: Biologische Anstalt Helgoland.

Lebour, M.V., 1937b. Larval and post-larval *Lima* from Plymouth. *Journal of the Marine Biological Association of the United Kingdom*, **21**, 705-710.

Lundälv, T., 1990. Effects of eutrophication and plankton blooms in waters bordering the Swedish west coast - an overview. *Water Pollution Research Reports*, **12**, 195-213.

MBA (Marine Biological Association), 1957. *Plymouth Marine Fauna.* Plymouth: Marine Biological Association of the United Kingdom.

Merrill, A.S. & Turner, R.D., 1963. Nest building in the bivalve genera *Musculus* and *Lima*. *Veliger*, **6**, 55-59.

Minchin, D., 1995. Recovery of a population of the flame shell, *Lima hians*, in an Irish bay previously contaminated with TBT. *Environmental Pollution*, **90**, 259-262.

Minchin, D., Duggan, C.B. & King, W., 1987. Possible effects of organotins on scallop recruitment. *Marine Pollution Bulletin*, **18**, 604-608.

Moore, C.G., Harries, D.B., Cook, R.L., Hirst, N.E., Saunders, G.R., Kent, F.E.A., Trigg, C. & Lyndon, A.R., 2013. The distribution and condition of selected MPA search features within Lochs Alsh, Duich, Creran and Fyne. Scottish Natural Heritage, Commissioned Report No. 566., 197 pp. http://www.snh.org.uk/pdfs/publications/commissioned_reports/566.pdf

Mullineaux, L.S. & Butman, C.A., 1990. Recruitment of encrusting benthic invertebrates in boundary-layer flows: A deep-water experiment on Cross Seamount. *Limnology and Oceanography*, **35** (2), 409-423.

O'Brien, P.J. & Dixon, P.S., 1976. Effects of oils and oil components on algae: a review. *British Phycological Journal*, **11**, 115-142.

Pawlik, J.R. & Butman, C.A., 1993. Settlement of a marine tube worm as a function of current velocity: Interacting effects of hydrodynamics and behavior. *Limnology and Oceanography*, **38** (8), 1730-1740.

Ringelband, U., 2001. Salinity dependence of vanadium toxicity against the brackish water hydroid *Cordylophora caspia*. *Ecotoxicology and Environmental Safety*, **48**, 18-26.

Ryland, J.S., 1970. *Bryozoans.* London: Hutchinson University Library.

Ryland, J.S., 1976. Physiology and ecology of marine bryozoans. *Advances in Marine Biology*, **14**, 285-443.

Salvini-Plawen, L.V., 1972. Cnidaria as food sources for marine invertebrates. *Cahiers de Biologie Marine*, **13,** 385-400.

Salvini-Plawen, L.V., 1977. Caudofoveata (Mollusca), Priapulida and apodous holothurian (*Labidoplax, Myriothrochus*) off Banyuls and throughout the Mediterranean. *Vie et Milieu, Paris*, **27**, 55-81.

Sastry, A., 1966. Temperature effects in reproduction of the bay scallop, *Aequipecten irradians* Lamarck. *The Biological Bulletin*, **130** (1), 118-134.

Seaward, D.R., 1990. *Distribution of marine molluscs of north west Europe.* Peterborough: Nature Conservancy Council.

Shumway, S.E., 1990. A review of the effects of algal blooms on shellfish and aquaculture. *Journal of the World Aquaculture Society*, **21**, 65-104.

Soule, D.F. & Soule, J.D., 1979. Bryozoa (Ectoprocta). In *Pollution ecology of estuarine invertebrates* (ed. C.W. Hart & S.L.H. Fuller), pp. 35-76.

Suchanek, T.H., 1993. Oil impacts on marine invertebrate populations and communities. *American Zoologist*, **33**, 510-523.

Tebble, N., 1976. *British Bivalve Seashells. A Handbook for Identification*, 2nd ed. Edinburgh: British Museum (Natural History), Her Majesty's Stationary Office.

Townsend, C.R., Scarsbrook, M.R. & Dolédec, S., 1997. The intermediate disturbance hypothesis, refugia, and biodiversity in streams. *Limnology and Oceanography*, **42** (5), 938-949.

Trigg, C. & Moore, C.G., 2009. Recovery of the biogenic nest habitat of *Limaria hians* (Mollusca: Limacea) following anthropogenic disturbance. *Estuarine, Coastal and Shelf Science*, **82**, 351-356.

Trigg, C., 2009. *Ecological studies on the bivalve Limaria hians (Gmelin).* Ph.D. Thesis, Heriot-Watt University.

Trigg, C., Harries, D., Lyndon, A. & Moore, C.G., 2011. Community composition and diversity of two *Limaria hians* (Mollusca: Limacea) beds on the west coast of Scotland. *Journal of the Marine Biological Association of the United Kingdom*, **91**, 1403-1412.

Ward, J.E. & Shumway, S.E., 2004. Separating the grain from the chaff: particle selection in suspension-and deposit-feeding bivalves. *Journal of Experimental Marine Biology and Ecology*, **300** (1), 83-130.

Widdows, J., Donkin, P., Brinsley, M.D., Evans, S.V., Salkeld, P.N., Franklin, A., Law, R.J. & Waldock, M.J., 1995. Scope for growth and contaminant levels in North Sea mussels *Mytilus edulis. Marine Ecology Progress Series*, **127**, 131-148.

Wildish, D., Kristmanson, D., Hoar, R., DeCoste, A., McCormick, S. & White, A., 1987. Giant scallop feeding and growth responses to flow. *Journal of Experimental Marine Biology and Ecology*, **113** (3), 207-220.

Wood, E. (ed.), 1988. *Sea Life of Britain and Ireland*. Marine Conservation Society. IMMEL Publishing, London