Serpula vermicularis reefs on very sheltered circalittoral muddy sand

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

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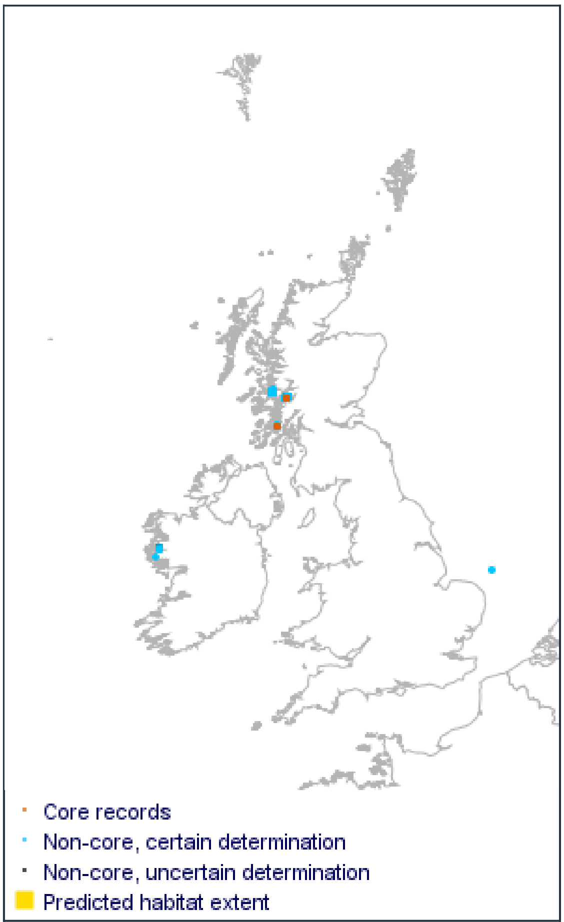
A colony of tube worms forming a small reef, Loch Creran.
Photographer: David Connor



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

Researched by Frances Perry, Catherine Wilding and Jacqueline Hill **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A5.613	*Serpula vermicularis* reefs on very sheltered circalittoral muddy sand
JNCC 2015	SS.SBR.PoR.Ser	*Serpula vermicularis* reefs on very sheltered circalittoral muddy sand
JNCC 2004	SS.SBR.PoR.Ser	*Serpula vermicularis* reefs on very sheltered circalittoral muddy sand
1997 Biotope	SS.CMS._.Ser	Serpula vermicularis reefs on very sheltered circalittoral muddy sand

Description

Large clumps ('mini reefs') of the calcareous tubes of *Serpula vermicularis*, typically attached to stones on muddy sediment in very sheltered conditions in sea lochs. A rich associated biota attached to the calcareous tube may include the sponge *Esperiopsis fucorum*, thin encrusting sponges, the ascidians *Ascidiella aspersa*, *Pyura microcosmus* and *Diplosoma listerianum* and fine hydroids such as *Halopteris catharina*. In shallow water dense *Phycodrys rubens* may grow on the reefs. Reefs from Loch Creran have been recently studied (Moore,1996; Poloczanska *et al*., 2004). The only other known site in UK for these reefs was Loch Sween, but living reefs are no longer found there (Hughes *et al*., 2008). Otherwise only known from Salt Lake, Clifden and Killary Harbour, Co. Galway, Ireland. (Information adapted from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al*., 1997a, b).

Depth range

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

Additional information

-

Listed By

- none -

Further information sources

Search on:

G G JNCC

Habitat review

Ecology

Ecological and functional relationships

- *Serpula vermicularis* normally occurs as individuals encrusted on hard surfaces. A tendency to form aggregations in certain conditions is reported but true reefs have an extremely limited distribution. It has been suggested that dense aggregations of *Serpula vermicularis* tubes only occur in enclosed and sheltered locations, where dispersal of larvae may be limited and where a suitable substratum is present. The hypothesis that reef formation occurs in Loch Creran due to limited larval dispersal is not currently backed up by any evidence. Loch Creran actually has quite a high flushing rate (Hughes pers. comm.) and there are many far more restricted sites in the area with no reef development. It is also questionable whether lack of suitable substratum is a factor leading to reef development. There are extensive areas of bedrock outcropping from the floor of Loch Creran but these typically support very limited and localised reef growth. Further, Chapman *et al.* (2007) suggest that the lower depth limit of reefs is not set by shortage of available substrata. The formation of reefs therefore is likely to be due to a complex interaction of many factors.
- In Loch Creran individual reefs are reported to reach a height of about 75 cm and 1 m across, although adjacent reefs may coalesce to form larger reefs up to 3 m across (Moore, 1996). Bosence (1979b) described reefs up to 2m in height and 1m across from Ardbear Lough but suggested that aggregated reefs could extend for several hundred metres.
- *Serpula vermicularis* requires a hard substratum on which to construct its tube. The most common substratum for settlement is bivalve shells. In Loch Creran it was particularly common on shells of *Pecten*, *Aequipecten* and *Modiolus*. Reefs form predominantly in areas where there is suitable substratum scattered throughout a muddy or muddy sand bottom. In this way, previously bare substratum can support dense aggregations of worms and a high diversity of associated species.
- The structure of *Serpula vermicularis* reefs is quite open, increasing surface and space for colonization, as well as for food and refuge, for an abundant and varied animal community. The rich associated fauna of organisms includes sessile organisms such as ascidians, hydroids, bivalves and other polychaete worms such as *Spirobranchus triqueter* and *Sabella pavonina*. There is also a mobile component of the associated macrofauna which is rich in amphipods, and also includes fish, crabs, whelks and echinoderms that use the reefs for feeding, refuge and egg-laying (Moore *et al.*, 1998b; Poloczanska *et al.*, 2004). The open structure appears to be related to the regular spacing of the apertures of the tubes at 10-15 mm apart which gives enough space for the expansion of the branchial crowns during feeding (Bosence, 1979b).
- Predation of *Serpula vermicularis* by several species has been described by Bosence (1979b) although the importance of the species as a food source is unknown. The wrasse *Ctenolabrus rupestris* and *Crenilabrus melops* were frequently seen biting serpulid tubes and extracting the worms. The starfish *Asterias rubens* was frequently seen with its stomach everted down the serpulid tubes. Bosence (1979b) also observed the urchins *Echinus esculentus* and *Psammechinus miliaris* feeding on serpulid tubes but thought it unlikely that they were feeding directly on the worms, which can withdraw into their tubes very rapidly, and were more likely to be eating the epifauna and epiflora on the tubes. Predation of *Serpula vermicularis* by *Cancer pagurus*, *Carcinus maenas*, *Asterias rubens* and

Ctenolabrus rupestris was observed in Salt Lake, Ardbear Lough (Minchin, 1987). However, long-term video monitoring of reefs in Loch Creran revealed very few instances of attempted predation on the worms (Poloczanska *et al*., 2004).

Seasonal and longer term change

The growth of *Serpula vermicularis* reefs may take many years so the major change over time is likely to be an increase in size of the reef. However, as growth of the reef proceeds, the old base is weakened by biological erosion by boring sponges and algae, and biting by fish and echinoderms. Segments of the reef then break off and provide new areas for larval settlement and this is the main way in which a reef growing from an original rocky substratum can extend outwards to cover areas of soft substratum (Bosence, 1979b). There may be seasonal changes in abundance of other species, such as hydroids, which often have lifespans less than a year, and due to periodic recruitment of larvae.

Habitat structure and complexity

The reef habitat created by aggregated *Serpula vermicularis* tubes can be up to 2m high (Bosence, 1979b). Initial growth is encrusting but after that the worms grow away from the substratum in a sinuous fashion, sometimes becoming intertwined and the reefs develop as new worms are added to old tubes. The reef is a structurally complex habitat as the open form of the aggregated tubes provides a large surface area and many spaces which supports a high diversity of sessile and mobile macrofauna. In Loch Creran, Scotland reefs were found growing in bedrock, boulders, stones, shells and man-made substrata (Moore *et al*., 1998b). Large reefs were only rarely found growing on rock.

Productivity

The community is predominantly faunal so productivity in the biotope is largely secondary. Red algae such as *Phycodrys rubens* and encrusting corallines are present in the biotope, although not in very high abundance and so levels of primary production are not likely to be high. Although no information was found regarding the diet of *Serpula vermicularis*, analysis of digestive enzymes suggests that quite large detrital particles may form an important part of the diet (Michel & De Villez, 1978). Several of the other species in the biotope, such as the ascidians and other polychaetes, are also suspension feeders. Phytoplankton, supplemented by non-living detritus, is likely to be the main food source for all these species (Hughes, pers. comm.). Secondary production could be substantial in large reefs.

Recruitment processes

- In the habitats in which this biotope is found, where water movement and exchange with coastal waters is limited, recruitment from local populations is particularly important because of the reduced supply of planktonic larvae from outside the system.
- In Loch Creran, larval settlement occurs predominantly from mid-June to mid October, peaking in late August-early September (Chapman *et al*., 2007). The length of the planktonic stage is not known but comparison with other serpulids suggests it would probably be between 6 days and 2 months. However, settling time may vary depending on salinity or food availability, and delayed settling may reduce discrimination of substrata for settlement.
- Reef development occurs by repeated settlement of larvae on the tubes of adults however evidence suggests that the larvae are not attracted to settle on adult tubes in

preference to substratum. Experiments in Loch Creran showed that *Serpula vermicularis* larvae settled on slate in preference to scallop shell. There was no evidence of enhanced recruitment to occupied of unoccupied adult tubes, suggesting that gregarious attraction is unlikely to be a factor causing reef formation (Chapman *et al.*, 2007).
- Recruitment of sessile organisms in the biotope, such as sponges, ascidians and hydroids, is almost entirely from planktonic sources. Some species have larvae that can disperse widely and these may arrive from distant locations. Others, particularly the hydroids and some ascidians have short lived planktonic larvae so dispersal distances are short and recruitment will largely be from local populations.
- Recruitment of the mobile predators and grazers may be through immigration of adults or via a larval dispersal phase. Mobile species such as decapod crustaceans, echinoderms and fish will settle from planktonic stages or migrate into the biotope.
- Red algae have non flagellate, and non-motile spores that stick on contact with the substratum. Norton (1992) noted that algal spore dispersal is probably determined by currents and turbulent deposition. However, red algae produce large numbers of spores that may settle close to the adult especially where currents are reduced such as in sheltered locations.

Time for community to reach maturity

Although the growth rates of individual *Serpula vermicularis* worms are relatively high (Bosence, 1979b), showing an average linear rate of 33mm/year for adult tubes (Hughes *et al.*, 2008), it is likely that reefs will take many years to develop. The reef develops upwards and outwards as larvae settle on to the tubes of existing worms and so it may take many periods of recruitment for reefs to become large. Many other species in the biotope, such as ascidians, hydroids and bryozoans exhibit annual recruitment and many are short lived so populations are likely to reach maturity rapidly. There are some slow growing species, such as encrusting coralline algae, which take longer to achieve significant coverage. Species diversity within the reef is likely to increase with time. However, the time to maturity of the biotope will depend on the time for reef development which is likely to be many years.

Additional information

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Preferences & Distribution

Habitat preferences

Depth Range	0-5 m, 10-20 m, 20-30 m
Water clarity preferences	
Limiting Nutrients	Not relevant
Salinity preferences	
Physiographic preferences	
Biological zone preferences	
Substratum/habitat preferences	
Tidal strength preferences	
Wave exposure preferences	

Other preferences

Additional Information

No text entered

Species composition

Species found especially in this biotope

- *Serpula vermicularis*

Rare or scarce species associated with this biotope

-

Additional information

No text entered.

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

Serpula vermicularis is found all around the British Isles (NBN Gateway, 2016), however, there are very few examples of *Serpula vermicularis* aggregations or 'reefs' (Dodd *et al*., 2009). Two *Serpula vermicularis* reefs are found in the UK, both of which are on the west coast of Scotland. One of these reefs was found in Loch Creran, and the other in Loch Teacuis. A third *Serpula vermicularis* reef has been found in the British Isles in County Galway, Ireland. Another reef was reported from Loch Sween but has since become extinct (Hughes *et al*., 2008).

Live reefs are considered rare (Dodd et al., 2009). *Serpula vermicularis* reefs are intricate, three-dimensional structures known to increase local habitat complexity and support a rich associated fauna (Bosence, 1979b; Poloczanska *et al*., 2004; Dodd *et al*., 2009).

Serpula vermicularis is the only species selected to represent the sensitivity of the biotope. Although the biotope has high species diversity (Chapman *et al*., 2012), no other species are included because the individual species present may vary and the loss of these species is not likely to affect the function and existence of the biotope.

Resilience and recovery rates of habitat

In Loch Creran, the patchy *Serpula vermicularis* reefs were recorded to have a maximum height often exceeding 50 cm and a width of 60 cm (Moore *et al*., 2003; Chapman *et al*., 2012). Minchin (1987) reported that the *Serpula vermicularis* reefs in Northern Ireland reached a maximum height of 1 m. Both the *Serpula vermicularis* reefs in Scotland and the west coast of Ireland are reported to be growing on successive serpulid settlements and tube debris can be found around the base of the reefs. These reefs are thought to be younger as no tube debris is present, although cores have not been taken so it is possible that any evidence has been covered by sediment deposition. Measurements of growth rates have shown that *Serpula vermicularis* can grow at up to 8 cm per year in Loch Creran (Hughes *et al*., 2008). The mean height of *Serpula vermicularis* reefs in Loch Teacuis is 26 ± 9 cm (Dodd *et al*., 2009). If the growth rates of *Serpula vermicularis* in Loch Creran were applied to the mean height of *Serpula vermicularis* in Loch Teacuis, then it would take three years and three months for the reefs to return (Dodd *et al*., 2009). Moore (unpublished in Holt *et al*., 1998) found that dense reefs of *Serpula vermicularis* up to about 15 cm in height were present on bare substratum after three months. The tallest *Serpula vermicularis* reefs recorded were 2 m high (Bosence, 1979b). A reef of this height would take would take at least 25 years to developed, based on the growth rate recorded in Loch Creran.

Serpula vermicularis reefs were first reported from Linne Mhuirich in Loch Sween, in 1979 (Bosence, 1979b). However, when this site was resurveyed in 1994 only empty tubes were found (O. Paisley & D. Hughes, pers. comm. Dodd *et al*., 2009). No recovery of the reefs had occurred by 2008 (Hughes *et al*., 2008). Mortality of *Serpula vermicularis* reefs has also occurred in Ireland (Bianchi *et al*., 1995; Henry, 2002). In both cases, it was not known why the reef was lost, or why the reef was not able to recover (Dodd *et al*., 2009). A 2015 Scottish Natural Heritage (SNH) survey of Loch Teacuis found that a significant reduction in the abundance and distribution of the *Serpula vermicularis* reef in the Loch had occurred since it was first described in 2006 (Kamphausen, 2015). Tulbure *et al.* (2015) quantified the change in the condition of the *Serpula vermicularis* reefs in Loch Creran since 2005. It was found that there had been a significant decline in the condition of the reefs, with half of the sites showing more than 70% collapse (Tulbure *et al*., 2015). It was supposed that a number of factors may have contributed to the decline in the condition of the serpulid reefs. These included changes in the planktonic community structure, change in land use in the Loch catchment area, and alterations in the localised weather (Tulbure *et al*., 2015).

Little has been written about the reproductive cycle of *Serpula vermicularis.* In the British Isles spawning occurs in the summer months (Elmhirst, 1922; Allen, 1915). Orten (1914) studied *Serpula vermicularis* in the south west of England and found that worms reproduced successfully at ten months old. It is thought that worms can survive for a number of years. But, there is no published evidence to support this supposition (Holt *et al*., 1998).

Serpula vermicularis reefs recorded in Ireland and Scotland are all in sheltered sea loch with restricted entrances. This has been suggested that sheltered conditions with a limited turnover of water are required for larval retention and therefore the development of the large number of *Serpula vermicularis* to enable the creation of reefs (Bosence, 1979b; Moore, 1996; Dodd *et al*., 2009). Dodd *et al.* (2009) suggested that the density of individuals in a system also needs to be at a certain level before the necessary number of larvae can be produced and retained triggering reef development. Poloczanska *et al.* (2004) reported that larvae settle near conspecifics in order to create monospecific reefs. *Serpula vermicularis* reefs are fragile and are reported to spread partly by fragmentation (Bosence, 1979b). Bosence (1979b) suggested that reef become more fragile with age. *Cliona celata* the boring sponge was suggested to contribute to the increasing fragility of reefs with age (Bosence, 1979b). Moore (1996) suggested that overgrowth of the *Serpula vermicularis* reefs by encrusting organisms may contribute to strengthening the colonies (cited from Holt *et al*., 1998).

Resilience assessment: This biotope is rare and there is a lack of knowledge regarding the life cycle of *Serpula vermicularis*, the correct conditions that create suitable habitat for reef formation. Therefore, where there is a lack of information on a specific pressure a conservative sensitivity assessment is given. If resistance to a pressure is assessed as 'High' then naturally, the resilience is also 'High'. If resistance to a pressure is 'Medium' and only part of the reef dies then there is the potential for there to be enough *Serpula vermicularis* produce enough larvae to recreate the lost reef. Although Moore (unpublished in Holt *et al*., 1998) suggested that reefs of *Serpula vermicularis* could rapidly recolonize an area, the situation within which the recolonization occurred was unclear. It is possible that there was a very high abundance of healthy, sexually mature *Serpula vermicularis* in close proximity. The lack of situational information given with these recovery rates makes it unwise to use this information for a recovery assessment. In the literature, any recorded loss of reef has never recovered (Minchin, 1987; Dodd *et al*., 2009). This biotope is also considered rare, and consequently, a more conservative estimate of resilience seems sensible, therefore, the resilience is given as 'Low'. For the pressures where resistance is assessed as 'Low' or 'None' resilience is assessed as 'Very low'. In the sheltered and enclosed areas where *Serpula vermicularis* reefs form recovery may not be possible if populations are mostly lost or completely lost. This is because the factor that enables the reefs to develop, i.e. limited water exchange keeping larvae in the local system, also limits the supply of larvae from coastal waters to replace populations if they disappear.

Hydrological Pressures

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

Serpula vermicularis is found throughout the British Isles (NBN, 2016), and its range extends through the North East Atlantic and the Mediterranean (Holt *et al.*, 1998). This range suggests it is tolerant of some temperature change. In Loch Creran in Scotland, the temperature regime within the main basin is similar to that in the adjacent sea with a low of about 6°C in February/March and a high of 13 - 15°C in August/September (Gage, 1972). The peak in larval recruitment of *Serpula vermicularis* in Loch Creran coincides with this peak in temperature (Chapman *et al.*, 2007). Additionally, Hughes *et al.* (2005) found the species to be tolerant of changes in temperature "with upper lethal limits exceeding any value that they could conceivably experience in the field".

Sensitivity assessment. At the pressure benchmark, the characterizing species *Serpula vermicularis* is not thought to be sensitive. Some of the other species in the biotope may be less tolerant of an increase in temperature, although overall species diversity is not expected to be significantly affected. Resistance and resilience have been assessed as 'High', which results in an assessment of as 'Not sensitive'.

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

Serpula vermicularis is found throughout the British Isles (NBN, 2016), and its range extends through the North East Atlantic and the Mediterranean (Holt *et al.*, 1998). It would be expected that in shallow enclosed areas, the temperature will fall during periods of cold winter weather so decreases in temperature are probably tolerated by reefs. Hughes *et al.* (2005) found the species to be tolerant of a wide range of temperatures.

Sensitivity assessment. At the pressure benchmark, the characterizing species *Serpula vermicularis* is not thought to be sensitive. Some of the other species in the biotope may be less tolerant of an increase in temperature, although overall species diversity is not expected to be significantly affected. Resistance and resilience have been assessed as 'High', which results in an assessment of as 'Not sensitive'.

Salinity increase (local)	None Q: Medium A: Medium C: Medium	Very Low Q: High A: Low C: Low	High Q: Medium A: Low C: Low

This biotope occurs in variable and full marine salinity regimes (Connor *et al.*, 2004). *Serpula vermicularis* is not found in areas where hypersaline conditions occur, such as rock pools or lagoons, so it seems likely that the species would be intolerant of increases in salinity. A long-term increase to hypersaline conditions would probably result in loss of reefs, and the loss of many of the other the other species that colonize the reefs.

Sensitivity assessment. Resistance is assessed as 'None', as a long-term change in the salinity regime at the benchmark would most likely cause the total mortality of the characterizing species and a large number of the other species found within the biotope. Resilience is assessed as 'Very low' due to the very unlikely recovery of the biotope, so that sensitivity is assessed as 'High'.

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

This biotope is recorded from both full marine and variable salinity regimes (Connor *et al.*, 2004).

Bosence (1979b) suggested that the layer of low salinity water in the upper layers of the water in Ardbear Loch in Galway, Eire is partly responsible for the lack of *Serpula vermicularis* individuals above a depth of 2 m. However, *Serpula vermicularis* are known to tolerate reduced salinities (Hartmann-Schröder, 1971; Mastrangelo & Passeri, 1975; cited in Moore *et al*., 1998b) and in Loch Creran in Scotland, individual specimens of *Serpula vermicularis* were commonly observed in shallow waters where salinities could fall to around 23 psu. Small enclosed lochs such as Loch Sween & Ardbear Loch are often subject to extremely variable salinity so the species seems to be tolerant of shorter term changes. *Serpula vermicularis* reefs were also observed in intertidal areas of Loch Creran during the 19th century, where salinity is likely to vary. Therefore, it seems likely that the species can tolerate some decreases in salinity. However, when reduced salinity interacts with variation in temperature, larval mortality occurs (Gray, 1976).

Sensitivity assessment. A long-term reduction in salinity from a variable regime will remove both *Serpula vermicularis* and the other species within this biotope from their optimal habitat conditions. It is likely that >25% of the *Serpula vermicularis* would die because of this change in salinity and consequently a resistance of **'Low'** is given. Therefore, resilience is assessed as **'Very low'** so that sensitivity is assessed as **'High'**.

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

The tidal flows within this biotope are recorded as weak (<1 knot) and very weak (negligible) (Connor *et al*., 2004). All of the *Serpula vermicularis* reefs recorded in Ireland and Scotland are found in sheltered sea lochs/loughs with restricted entrances. This has led to the suggestion that sheltered conditions with a limited turnover of water are required for larval retention and, therefore, the development of *Serpula vermicularis* reefs (Bosence, 1979b; Moore, 1996 cited from Dodd *et al*., 2009). In Loch Creran, no reefs were recorded in the outer section of the loch beyond the narrows at Sgeir Calliach, despite the presence of suitable depths and substrata. This is a well-flushed section of the loch, where the larvae of *Serpula vermicularis* will presumably be at lower concentrations than further up the loch (Moore, 1998b). Therefore, the biotope is likely to be intolerant of an increase in water flow rate as larvae are likely to be taken away from the reefs, old worms will die and, without a supply of new individuals, the reef will die. With the collapse of dead *Serpula vermicularis* reefs, species diversity will decline significantly because the open structure of the reefs provides substratum and crevices for many other organisms.

Sensitivity assessment. Although water flows seem to be a very important environmental factor for the growth of *Serpula vermicularis* reefs, this pressure is very unlikely to have a negative impact on the biotope at the level of the benchmark. Therefore, resistance and resilience are assessed as 'High', which give the biotope an overall assessment of 'Not sensitive'.

Emergence regime 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

This biotope does not occur in the intertidal, and consequently an increase in emergence is considered not relevant to this biotope.

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

This biotope occurs in sea lochs where wave exposure is recorded as sheltered to extremely sheltered (Connor *et al*., 2004). The *Serpula vermicularis* reefs are open and quite fragile structures and are not likely to be resistant of wave exposure. No reefs are reported at depths of zero metres, which may be the effect of turbulence on larval recruitment (Champan *et al*., 2007). Tulbure *et al*. (2015) found that in Loch Creran the more exposed areas of the Loch contained lower total coverage of *Serpula vermicularis*.

Sensitivity assessment. An increase in wave exposure may damage existing reefs, while a decrease might increase the available space for colonization. However, an increase in the pressure at the benchmark is very unlikely to affect the biotope. Therefore, resistance and resilience are assessed as 'High', which give the biotope an overall assessment of '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	Low Q: High A: Medium C: Medium	Very Low Q: High A: Low C: Low	High Q: High A: Low C: Low

There is no information regarding the tolerance of *Serpula vermicularis* to deoxygenation. Cole *et al*. (1999) suggest possible adverse effects on marine species below 4 mg/l and probable adverse effects below 2 mg/l. Bosence (1979b) observed that the lower limit of larval settlement in Ardbear Lough, Eire coincided with mud-rich and possibly oxygen poor water. Gage (1972) found the dissolved oxygen concentration in the lower basin of Loch Creran in Scotland, where *Serpula vermicularis* reefs form, did not fall below 87% saturation. Therefore, the species, and the larvae, in particular, may be intolerant of deoxygenated water. Other species in the biotope may also be intolerant of changes in oxygen availability resulting in a possible loss of species diversity.

Sensitivity assessment. The resistance of this biotope to de-oxygenation at the level of the benchmark is 'Low', which leads to a resilience of 'Very low'. Therefore, the overall sensitivity of the biotope to this pressure at the benchmark is 'High'.

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

This pressure relates to increased levels of nitrogen, phosphorus and silicon in the marine environment compared to background concentrations. 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 microalgal 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. Due to the 'remarkably consistent' effect of marine pollutants on species diversity, this finding is probably relevant to this biotope (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 (Johnston & Roberts, 2009).

Sensitivity assessment. Moderate nutrient enrichment, especially in the form of organic particulates and dissolved organic material, is likely to increase food availability for all the suspension feeders within the biotope. However, long-term or high levels of organic enrichment may result in eutrophication and have indirect adverse effects, such as increased turbidity, increased suspended sediment, increased risk of deoxygenation and the risk of algal blooms. However, this biotope is assessed as

Not sensitive at the pressure benchmark of compliance with good status as defined by the WFD.

Organic enrichment	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

Organic enrichment leads to organisms no longer being limited by the availability of organic carbon. The consequent changes in ecosystem function 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 microalgal blooms (Bricker *et al*., 1999, 2008). Indirect adverse effects associated with organic enrichment include increased turbidity, increased suspended sediment and the increased risk of deoxygenation.

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. Due to the 'remarkably consistent' effect of marine pollutants on species diversity, this finding is probably relevant to this biotope (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.

Organic effluent from an alginate factory n Loch Creran in Scotland appeared to be responsible for the elimination of *Serpula vermicularis* reefs for a distance of about 1 km and may have reduced reef development at greater distances (Moore *et al*., 1998b). However, this level of organic pollution was extreme, with much of the seabed becoming covered in a thick bacterial mat, and does not give any indication of the intolerance of *Serpula vermicularis* reefs to an increase in organic enrichment at the benchmark. Species diversity may decline but the overall impact on reefs is unknown.

Sensitivity assessment. Little empirical evidence was found to support an assessment of this biotope at this benchmark. The lack of direct evidence for the characterizing species has resulted in this pressure being assessed as 'No evidence'.

Physical Pressures

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

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

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

If rock were replaced with sediment, this would represent a fundamental change to the physical character of the biotope and the species would be unlikely to recover. The biotope would be lost.

Sensitivity assessment. Resistance to the pressure is considered 'None', and resilience 'Very low'. Sensitivity has been assessed as 'High'.

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

In Loch Teacuis, *Serpula vermicularis* reefs were recorded to grow on rocks and amongst the *Laminaria saccharina* holdfasts (Dodd *et al*., 2009). In Loch Creran, *Serpula vermicularis* grows mainly on bivalve shells on muddy sand (Dodd *et al*., 2009). *Serpula vermicularis* typically grow up from a shell, cobble or boulder substratum on muddy sand to produce patch reefs (Chapman *et al*., 2012). The species needs to be able to attach to a hard substratum, and can't settle on to soft sediment. Therefore, a change in the Folk class within this biotope is not going to affect the characterizing species, as long as patches of hard substratum remain.

Sensitivity assessment. As this pressure won't affect *Serpula vermicularis* both the resistance and resilience have been assessed as 'High', giving the biotope an assessment of 'Not sensitive'. Due to the large amount of soft sediment that can be found within this biotope, there is likely to be a large number of infaunal species, that are likely to be affected by a change in the pressure at the benchmark.

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

Serpula vermicularis reefs are always attached to a hard substratum as the larvae have to be able to settle on a stable anchor point. However, these solid anchor points can be bivalve shells, pebbles, cobbles, and boulders, all of which could be extracted under this pressure. The removal of this substratum would remove all of the characterizing species, *Serpula vermicularis*, as well as a large majority of the other species found in this biotope.

Sensitivity assessment. The resistance of this biotope to this pressure is 'None', and the resilience is 'Very low', which results in a sensitivity assessment of 'High'.

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

Serpula vermicularis are fragile and can be easily damaged. For example, in Loch Creran severe damage, although only on a local scale, was caused by movement of mooring blocks and chains (Moore, 1996). Although the effects were localized, mooring had reduced colonies to rubble within a radius of 10 m in one instance, and extensive damage was reported within 50 m of salmon cages (Holt *et al*., 1998). Holt *et al.* (1998) suggested that fishing activity could be very damaging but that no evidence of damage had yet been observed. Although individual worms survived and were seen to continue feeding, the reefs were broken up so that the value of the habitat was greatly diminished. A passing scallop dredge is likely to result in more damage. In Loch Creran, individual reefs were reported to reach a height of about 75cm and 1 m across, although adjacent reefs could coalesce to form larger reefs up to 3 m across (Moore, 1996). A passing beam trawl or scallop dredge could destroy the entire reef. Pieces of reef broken off from the main reef may continue to grow as new worms attach to fragments (Bosence, 1979b).

Sensitivity assessment. The resistance of this biotope to this pressure is 'None', and the resilience is 'Very low', which results in a sensitivity assessment of 'High'.

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

Due to the epiphytic nature of the characterizing species within this biotope, the physical effect of penetration will be extremely similar to the effects of abrasion and disturbance. Therefore, the sensitivity assessment for abrasion and disturbance is thought to be relevant for this pressure as well.

Sensitivity assessment. The resistance of this biotope to this pressure is 'None', and the resilience is 'Very low', which results in a sensitivity assessment of 'High'.

Changes in suspended solids (water clarity)	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

Siltation can have a negative impact on site selection by Serpulid (or full species name) larvae (Rodriguez *et al.*, 1993). Bosence (1979b) concluded from observations and from transplant experiments, that the lower depth limit of *Serpula vermicularis* was probably determined by suspended sediment and deoxygenation. In contrast, Moore *et al.* (1998b) found no horizontal layers of suspended mud in Loch Creran, and although the authors do not rule out the possibility that storm-generated, suspended mud may inhibit reef development, the lower limit of reefs could also be due to inadequate current velocities for suspension feeding. Chapman *et al.* (2007) suggested that the lower depth limit was a result of a depth-correlated settlement response of larvae. A supply of suspended sediment may be important to *Serpula vermicularis* because the species requires a supply of particulate matter for suspension feeding.

Sensitivity assessment. There is a lack of empirical evidence to suggest how the pressure at the benchmark might affect this biotope. An increase in suspended sediment may affect the ability of *Serpula vermicularis* larvae to settle. In addition, an increase in suspended sediment may change the rate at which *Serpula vermicularis* has to clean its branchial plume. A decrease in the level of suspended sediment could reduce the amount of particulate food in the water column and consequently reduce food availability. However, due to the lack of information a sensitivity assessment of 'No evidence' is given.

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

Serpula vermicularis is attached permanently to the substratum by a calcareous tube, which in aggregating reef forming individuals extends above the substratum as new worms are added to old tubes. For example, in Loch Creran individual reefs were reported to reach a height of about 75 cm (Moore, 1996). The reef structure is also open, creating cracks and crevices where sediment could collect. Therefore, many individuals of *Serpula vermicularis*, and the associated fauna of sponges, ascidians and hydroids, may avoid 5 cm of smothering material. Some of the mobile species in the biotope may be able to avoid the factor. The deposition of silt is thought to create unfavourable conditions for the settlement of *Serpula vermicularis* larvae (Cotter *et al.*, 2003).

Sensitivity assessment. At the level of the benchmark, a portion of the reef may be lost due to the sediment deposition. Therefore, resistance is assessed as 'Medium'. In addition, it is also likely that too much sediment on the surface of rocks or tubes would prevent settlement of larvae (Holt *et al*., 1998; Cotter *et al*., 2003) and so may also reduce the long-term growth of the reef. At the level of the resistance, resilience is assessed as 'Low', which gives the biotope a sensitivity assessment of 'Medium'.

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

The mean height of *Serpula vermicularis* reefs in Loch Teacuis is 26 ± 9 cm (Dodd *et al*., 2009). In other reefs, such as those in Loch Creran, reefs have been recorded to have a maximum height often exceeding 50 cm (Moore *et al*., 2003). This difference in reef height will mean that the effect of this pressure will vary depending on the reef which is going to be affected. Therefore, each reef should be assessed on a case by case basis. Taking into consideration the reef in Loch Teacuis, the pressure at the benchmark would smother a vast majority of the reef, causing the worms to asphyxiate as gaseous exchange would be inhibited and the worms would also not be able to feed.

Sensitivity assessment. At the benchmark, a large proportion of the biotope would be smothered. Resistance is assessed as 'None', Resilience is assessed as 'Very low', and the overall assessment of the sensitivity of this biotope is assessed as 'High'.

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	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.

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 – 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.

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	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 for the effect of this pressure on the characterizing species within this biotope was found.

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

Although several species of serpulid polychaetes have been introduced into British waters none are reported to compete with *Serpula vermicularis* (Eno *et al*., 1997). However, there is always the potential for introduced species to either compete with or prey upon *Serpula vermicularis.*

Sensitivity assessment. There is a chance that an INIS might be able to invade this biotope. Depending on which INIS species is introduced, this biotope may remain, but with reduced species richness due to the loss of some species. However, at present, there is insufficient evidence to support an assessment of this pressure. Due to the constant risk of new invasive species, the 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 information on diseases of *Serpula vermicularis* was found. The species is known to be parasitized by the protozoan *Haplosporidium parisi* (Ormieres, 1980) but the effects of this infestation are unknown. There are no reports of loss of the biotope from disease. However, there is always the potential for this to occur. There is insufficient evidence to assess the effect of the pressure on this biotope; therefore, an assessment of 'No evidence' has been given.

Removal of target species	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

No evidence to suggest that the characterizing species within this biotope are targeted by commercial fisheries.

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

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The characterizing species within this biotope could easily be incidentally removed from this biotope as by-catch when other species are being targeted. The loss of these species and other associated species would decrease species richness and negatively impact on the ecosystem function.

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 ‘Very low’, with recovery only being able to begin when the harvesting pressure is removed altogether. This gives an overall sensitivity score of ‘High’.

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