Sparse *Modiolus modiolus*, dense *Cerianthus lloydii* and burrowing holothurians on sheltered circalittoral stones and mixed sediment

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

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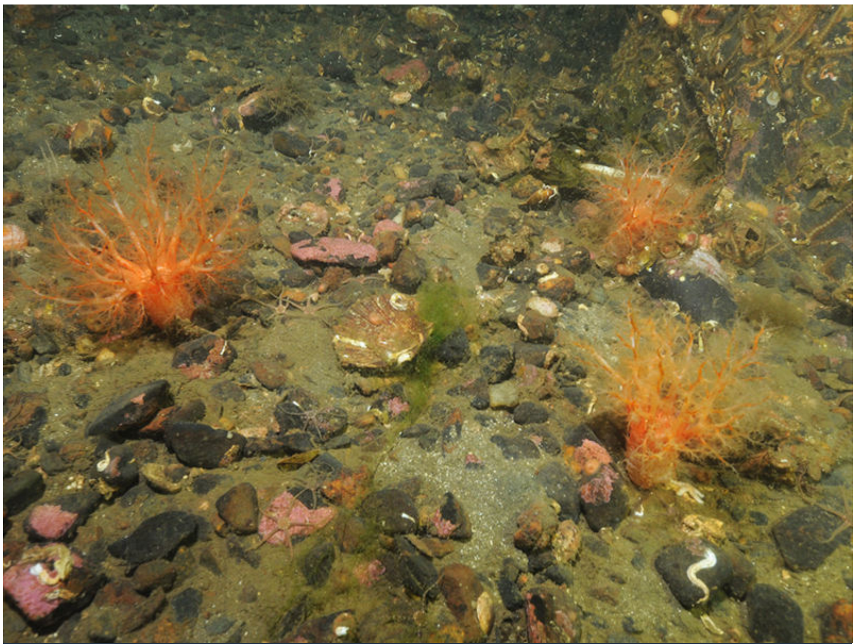
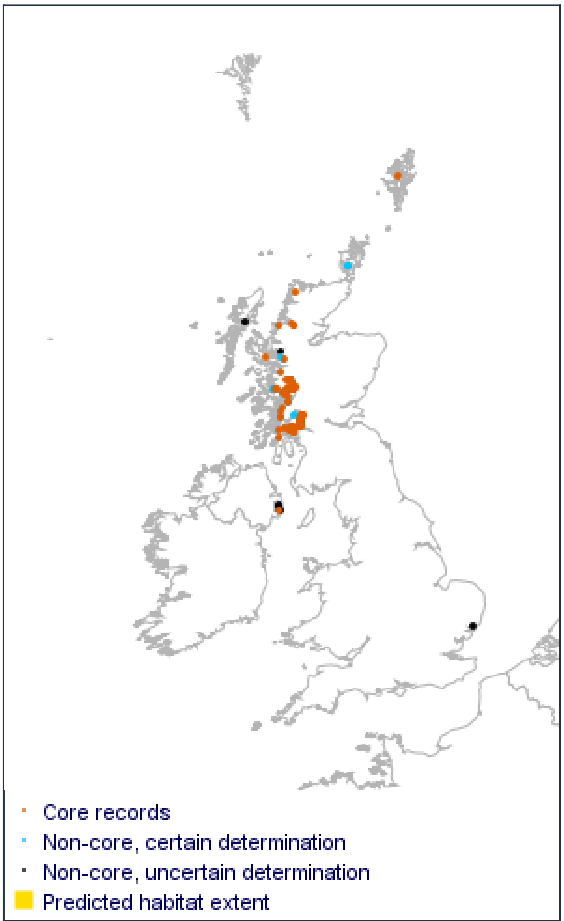


Sparse *Modiolus modiolus*, dense *Cerianthus lloydii* and burrowing holothurians on sheltered circalittoral stones and mixed sediment
Photographer: Keith Hiscock



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

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

Summary

UK and Ireland classification

EUNIS 2008	A5.442	Sparse *Modiolus modiolus*, dense *Cerianthus lloydii* and burrowing holothurians on sheltered circalittoral stones and mixed sediment
JNCC 2015	SS.SMx.CMx.ClloModHo	Sparse *Modiolus modiolus*, dense *Cerianthus lloydii* and burrowing holothurians on sheltered circalittoral stones and mixed sediment
JNCC 2004	SS.SMx.CMx.ClloModHo	Sparse *Modiolus modiolus*, dense *Cerianthus lloydii* and burrowing holothurians on sheltered circalittoral stones and mixed sediment
1997 Biotope	SS.CMX._.ModHo	Sparse *Modiolus modiolus*, dense *Cerianthus lloydii* and burrowing holothurians on sheltered circalittoral stones and mixed sediment

Description

Pebbles and cobbles on muddy shell gravel in sea lochs with dense *Cerianthus lloydii* and sparse *Modiolus modiolus*. Large burrowing holothurians (many only extend their tentacles above the sediment surface seasonally) include *Psolus phantapus*, *Paracucumaria hyndmani*, *Thyonidium commune*, *Thyone fusus* and *Leptopentacta elongata*. This biotope is well developed in the Clyde sea lochs, although many examples are rather species-poor. Some examples in south-west Scotland sea lochs have greater quantities of boulders and cobbles and therefore have a richer associated biota (compared with other sheltered *Modiolus* bed biotopes such as SCR.ModHAs). Examples in Shetland are somewhat different in having the cucumber *Cucumaria frondosa* amongst sparse *Modiolus* beds and a slightly different balance in abundance of other species; for example the brittlestar *Ophiopholis aculeata* is more abundant in these far northern examples in the voes and narrows (see MCR.Oph.Oacu).

Depth range

-

Additional information

-

Listed By

- none -

Further information sources

Search on:

G G G JNCC

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The species composition found in this biotope changes depending on the location in the British Isles. The core records show that the biodiversity of this biotope can vary, with especially species poor examples coming from the Clyde sealochs (Connor *et al.*, 2004). However, the bivalve mollusc *Modiolus modiolus* and the burrowing anemone *Cerianthus lloydii* are always present within the biotope and these two species are consequently considered important characterizing. Within this biotope *Modiolus modiolus* does not create the extensive biogenic beds that are found in other *Modiolus modiolus* biotopes, such as SS.SBR.SMus.ModT. Instead this species is recorded as occasional within this biotope, with *Cerianthus lloydii* being recorded as frequent. Other species within the biotope include a variety of large burrowing holothurians. Although holothurians are likely to contribute significantly to the biodiversity of the biotope, their burrowing nature has led to the suggestion that they are in fact under recorded. Without the *Modiolus modiolus* and the holothurians, this biotope is very similar to SS.SMx.CMx.ClloMx. Therefore, the sensitivity assessment focuses on the important characteristic species *Modiolus modiolus* and *Cerianthus lloydii*. The sensitivity of other characteristic species is discussed where relevant.

Resilience and recovery rates of habitat

In general, observations on disturbed *Modiolus modiolus* beds, manipulative experiments and life history characteristics suggest that recruitment to adult populations varies and that time to recover may be prolonged. It should be noted that the recovery rates are only indicative of the recovery potential. Recovery of impacted populations will always be mediated by stochastic events and processes acting over different scales including, but not limited to, local habitat conditions, further impacts and processes such as larval-supply and recruitment between populations.

Witman (1984, cited in Suchanek 1985) cleared 115 cm^2 patches in a New England *Modiolus modiolus* bed. None of the patches were recolonized by the horse mussel after two years, 47 % of the area being colonized by laminarian kelps instead (Witman pers. comm., cited in Suchanek 1985). On Georges Bank in the north western Atlantic, *Modiolus modiolus* larvae recruited onto test panels within two years (Collie *et al*. 2009). However, , due to slow growth (and recruitment) of the species Collie *et al.* (2009) suggested that it would take 10–15 years for clusters of large individuals to form. Similarly, Mair *et al*. (2000, cited from OSPAR, 2009), reported recruitment into disturbed sediments a few years after pipeline was laid. Anwar *et al*. (1990) reported a substantial population on the legs of an oil rig, 10 years after installation. They was suggested that growth was enhanced in this situation due to a lack of predation (Anwar *et al*., 1990). The evidence suggests that in areas that are artificially cleared or free of predators, recruitment may be relatively rapid where there is a supply of larvae. However, the evidence refers to dense settlement of juveniles rather than the development of reefs and such settlements may be relatively ephemeral or in habitats that are not suitable for the long-term establishment of a bed.

Modiolus modiolus is long-lived. Individuals of 10 cm shell length from Northern Ireland were estimated to be between 14 and 29 years old (Seed & Brown 1975, 1978). Individuals from Shetland of 10 cm shell length were estimated to be between 11 and 17 years old (Comely, 1981), and those from Norway were 10 – 18 (13 – 19) years old (Wiborg, 1946). Anwar *et al.* (1990) report that the oldest individual studied, from the northern North Sea at a depth of 73–77 m, was approx. 48 years old. In Norway, *Modiolus modiolus* has been reported as sexually mature at three years, although most individuals mature at an age of 5 –6 (and up to eight) years (Wiborg, 1946). Around the Isle of Man, the youngest mature individuals were 3 – 4 years old (Jasim & Brand 1989). In Canada, the earliest mature individuals were four years old, and most individuals did not reach maturity until the age of 7 – 8 years (Rowell 1967). In Northern Ireland, most individuals mature at a shell length of 4–5 cm (4–6 years), but some mature at a shell length of 1–2 cm (Seed & Brown 1977).

Reproduction and spawning duration varies with depth and location. Dinesen & Morton (2014) compared gametogenesis and spawning season in four subtidal populations of *Modiolus modiolus* from a depth of 15 m. They showed that both may occur simultaneously. In Strangford Lough, gametogenesis and spawning may occur throughout the year, with peak months varying between years (Brown, 1984). Geographic differences play an important role in the timing of maturity and there appear to be differences between populations even within short distances at similar depths. Similarly, populations in the same area but at different depths can show variation in both maturation and spawning (Dinesen & Morton, 2014).

The larvae are in the water column of about four weeks after fertilization (Dinesen & Morton, 2014). Comely (1978) observed that spat settled on established adults, and larger individuals were found within the byssus thread where they had either settled or migrated to after settlement. Dinesen & Ockelmann (unpublished data, cited in Dinesen & Morton, 2014) observed that viable larvae settle preferentially in response to the exhalant water of adults. Translocation of horse mussels *Modiolus modiolus* to areas of 'cultch' (broken scallop shells) in Strangford Lough, Northern Ireland, as part of a programme of work to restore populations destroyed by scallop dredging, also indicated that settlement of *Modiolus modiolus* larvae was directly enhanced by the presence of adults on the sea floor (Davoult *et al*. 1990). Where beds are cleared or reduced in size, recolonization may therefore be hampered by the lack of adults.

Sources and sink areas for recruitment are influenced by prevailing hydrographic conditions and current dynamics. The Strangford Lough populations appear to be self-recruiting (Brown 1990; Elsässer et al. 2013). In open areas with free water movement larvae are probably swept away from the adult population, and such populations are probably not self-recruiting but dependent on recruitment from other areas, which is in turn dependent on the local hydrographic regime (Holt *et al*. 1998).

Recruitment in *Modiolus modiolus* is sporadic and highly variable seasonally, annually or with location (Holt *et al*., 1998). Dinesen & Morton (2014) state that, post impact recovery times are long and dependent on local and mega-population distributions. Any factor that reduces recruitment is likely to negatively affect the population in the long-term. However, any chronic environmental impact may not be detected for some time in a population of such a long -lived species and populations may survive as 'relicts' in habitats that are now unsuitable. Scottish populations varied, with 'normal' recruitment occurring in areas of strong currents, resulting in a relatively young population, while recruitment was negligible in areas of quiet water that resulted in an ageing population (Comely, 1978). In a deep water population no recruitment had occurred for a number of years and the population was old, possibly senile and dying out (Comely, 1978; OSPAR, 2009). Newly-settled horse mussels exhibit rapid growth prior to reaching maturity, investing energy in growth rather than reproduction. Selection favours rapid growth to a size that is relatively immune to predation. Only the largest starfish and crabs can open mussels greater than 45-60mm and large horse mussels are thought to be largely predator free (Roberts, 1975; Seed & Brown, 1978; Holt *et al*., 1998). Comely (1978) noted that *Modiolus modiolus* <40mm were rarely found away from large horse mussels.

Little evidence was found to support recovery assessments for *Cerianthus lloydii*. The biological trait review by MES (2010) suggested that the genus *Cerianthus* would be likely to have a low recovery rate following physical disturbance based on its long-lifespan and slow growth rate. They suggested that 'recovery of biomass and age-structured populations will be relatively slow (MES 2010). The MES (2010) review also highlighted that there were gaps in information for this species and that age at sexual maturity and fecundity is unknown, although the larvae are pelagic (MES 2010). No empirical evidence was found for recovery rates following perturbations for *Cerianthus lloydii*. This species has limited horizontal mobility and re-colonization via adults is unlikely (Tillin & Tyler-Walters, 2014).

Resilience assessment. Overall, therefore, while some populations of *Modiolus modiolus* are probably self-sustaining it is likely that a population that is reduced in extent or abundance will take many years to recover, and any population destroyed by an impact will require a very long time to re-establish and recover, especially since larvae depend on adults for settlement cues and juveniles require the protection of adults to avoid intense predation pressure. The available evidence for *Modiolus modiolus* suggests that recovery from significant impacts could be inhibited by the lack of adults to provide settlement cues and protection to larvae and juveniles. It should be noted that this biotope is characterized by sparse clumps of *Modiolus modiolus* rather than biogenic beds or reefs. For recovery of sparse *Modiolus modiolus* is likely to take less time to recover than beds forming biogenic reef of *Modiolus modiolus. Cerianthus lloydii* is relatively common and occurs in a range of habitat types, which suggests that in many areas there is some larval supply. It has been assumed that *Cerianthus lloydii* will recover faster than *Modiolus modiolus*, and therefore the following resilience assessment is based on estimates for *Modiolus modiolus.* Resilience is assessed as 'Low' (10 – 25 years) where resistance is 'None' or 'Low'. Where resistance is assessed as 'Medium' where (less than 25% of the bed is removed) and the habitat remains suitable for recolonization, then resilience is probably Medium (2 - 10 years).

Hydrological Pressures

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

Modiolus modiolus is a boreal species that reaches its southern limit in UK waters and forms beds of large individuals only in the north of Britain and Ireland (Hiscock *et al*., 2004). The depth range of *Modiolus modiolus* increases at higher latitudes with intertidal specimens more common on northern Norwegian shores where air temperatures are lower (Davenport & Kjørsvik, 1982). Little direct information on temperature tolerance in *Modiolus modiolus* was found, however, its upper lethal temperature is lower than that for *Mytilus edulis* (Bayne 1976) by about 4°C (Henderson, 1929, cited in Davenport & Kjørsvik, 1982). Subtidal populations are protected from major, short-term changes in temperature by their depth. However, Holt *et al*., (1998) suggested that because *Modiolus modiolus* reaches its southern limit in British waters it may be susceptible to long-term increases in summer water temperatures. Hiscock *et al.* (2004) suggest that warmer seas may prevent recovery of damaged beds and recruitment to undamaged beds so that decline in occurrence of beds can be expected at least in the south of their range. Declines of horse mussel beds in Strangford Lough (Magorrian, 1995) may be linked to increased water temperatures but other factors such as trawling have also contributed to changes.

Cerianthus lloydii adults are locally abundant in many localities on all coasts of the British Isles and in some areas are common on the shore. This species occurs on all western coasts of Europe from Greenland and Spitzbergen south to Biscay. Larvae, but not adults, have been recorded from the Mediterranean (Marine Species Information Portal). There is no further information available on the temperature tolerance of *Cerianthus lloydii*.

Sensitivity assessment. *Modiolus modiolus* is a boreal species, and the fact that dense aggregations seem to reach their southerly limit around British shores suggests this species would be sensitive to long-term increases in temperature. Adult populations may be unaffected at the pressure benchmark and, in such long-lived species, an unfavourable recruitment may be compensated for in a following year. *Cerianthus lloydii* is present throughout the British Isles and is likely to be able to tolerate a change in temperature at the pressure benchmark. Resistance to an acute and chronic change in temperature at the pressure benchmark is therefore assessed as 'High' and recovery as 'High' (within two years) and the biotope is considered 'Not Sensitive'. It should be noted that the timing of acute changes may lead to greater impacts, temperature increases in the warmest months may exceed thermal tolerances whilst changes in colder periods may stress individuals acclimated to the lower temperatures. Sensitivity to longer-term, broad-scale perturbations such as increased temperatures from climate change would however be greater, based on the extent of impact.

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

Modiolus modiolus is a boreal species that reaches its southern limit in UK waters and forms beds of large individuals only in the north of Britain and Ireland (Hiscock *et al*. 2004). Davenport and Kjørsvik (1982) suggested that its inability to tolerate temperature change was a factor preventing the horse mussel from colonising the intertidal in the UK. Intertidal specimens were more common on northern Norwegian shores (Davenport & Kjørsvik 1982). Subtidal populations are protected from major, short-term changes in temperature by their depth.

Cerianthus lloydii adults are locally abundant in many localities on all coasts of the British Isles and in some areas are common on the shore. This species occurs on all western coasts of Europe from Greenland and Spitzbergen south to Biscay. No further information is available on the temperature tolerance of *Cerianthus lloydii*.

Sensitivity assessment. *Modiolus modiolus* is a boreal species with beds in higher latitudes exposed to colder temperatures than experienced at the southern limit of its range in the UK. Due to the natural range of *Cerianthus lloydii*, it is unlikely that a change in the pressure at the benchmark will have any significant impact on the health of this biotope. Therefore, this biotope is considered to have 'High' resistance to decreased temperatures at the benchmark. Resilience is assessed as 'High' (by default) and this biotope is considered to be 'Not sensitive'.

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

Modiolus modiolus is an osmocomformer and, in short-term fluctuating salinities, valve closure limits exposure to salinity changes in the surrounding waters, although slow diffusion through the byssal aperture means that the osmolarity of internal fluids will eventually increase (Shumway, 1977; Davenport & Kjørsvik, 1982). Experimental evidence for short-term tolerances of *Modiolus modiolus* to increased salinities is provided by Pierce (1970). *Modiolus modious* was exposed to a range of salinities between 1.5 and 54 psu and survived for 21 days (the duration of the experiment) at salinities between 27 and 41 psu (Pierce, 1970). No evidence could be found for osmoregulation by *Cerianthus lloydii*. Based on the lack of reports of *Cerianthus lloydii* in areas within reduced salinity regimes this species is considered to be restricted to variable and fully marine environments.

Sensitivity assessment. This biotope is recorded from full and variable salinity regimes. Therefore, if there were to be an increase in the salinity regime of this biotope the conditions would become hypersaline. There is no evidence to suggest that either of the species is ever found in hypersaline conditions. And both are usually found in stable circalittoral biotopes. The biotope is assessed to have a resistance of 'None' to the pressure at the benchmark, and a resilience of 'Low', giving this biotope a sensitivity of 'High'.

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

This biotope is recorded from both fully marine and variable salinity regimes. A decrease in the pressure at the benchmark would create reduced salinity conditions (18 – 30 psu). Dinesen & Morton, (2014) inferred that the lower, long-term salinity tolerance of adult *Modiolus modiolus* is likely to be about 26, based on its distribution in the Baltic Sea. This is supported by observations of Davenport & Kjørsvik (1982) who reported the presence of large horse mussels in rock pools at 16 psu in Norway, subject to freshwater inflow, and noted that they were probably exposed to lower salinities. By keeping the shell valves closed the fluid in the mantle cavity of two individuals was found to be at a salinity of 28 – 29 despite some hours of exposure (Davenport & Kjørsvik, 1982). Short-term tolerances to a salinity of 15 were similarly identified for *Modiolus modiolus* from the White Sea, north west Russia (where salinity is typically 25), whereas salinity levels of between 30 and 35 appeared optimal. However, after a winter and spring of extremely high rainfall, populations of *Modiolus modiolus* at the entrance to Loch Leven (near Fort William) were found dead, almost certainly due to low salinity outflow (K. Hiscock, pers. comm.). Holt *et al*., (1998) reported that dense populations of very young *Modiolus modiolus* do occasionally seem to occur subtidally in estuaries, but the species is more poorly adapted to fluctuating salinity than many other mussel species (Bayne, 1976) and dense populations of adults are not found in low salinity areas.

Pierce (1970) exposed *Modiolus* sp. to range of salinities between 1.5 and 54 psu and reported that *Modiolus modiolus* survived for 21 days (the duration of the experiment) between 27 and 41 psu. Shumway (1977) exposed individual *Modiolus modiolus* to simulated tidal, (sinusoidal) fluctuations between full seawater (salinity 32‰) and 50% freshwater and to more abrupt changes in salinity in laboratory experiments. Individual *Modiolus modiolus* that were able to close their valves survived 10 days exposure to salinity changes compared with individuals which had their shells wedged open that survived for 3 days of the experiment only. Exposure to reduced salinities has been observed to lead to reduced ctenidial ciliary stroke (after 3 days at a salinity of 15 and 10°C, Schlieper *et al*., 1958) and increased intracellular liquid/water (Gainey,1994).

Based on the lack of reports of *Cerianthus lloydii* in areas within reduced salinity regimes this species is considered to be restricted to variable and fully marine environments.

Sensitivity assessment. The available evidence indicates that *Modiolus modiolus* is an osmocomformer and is able to tolerate decreases in salinity for a short period. However, a decrease in salinity at the pressure benchmark would be considered to result in the mortality of all adults within the biotope over the course of a year. This assessment is supported by observed distribution across different salinity regimes (Connor *et al*., 2004, Dineson & Morton, 2014) and laboratory experiments (Shumway, 1977, Pierce, 1970) which suggest that a change at the pressure benchmark would exceed the lower threshold tolerance of adults over the course of a year. It also considered highly likely that the population of *Cerianthus lloydii* would suffer mortality at the pressure benchmark. Resistance is 'None', resilience is 'Low', giving the biotope a sensitivity of 'High'.

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

Adult *Modiolus modiolus* occur commonly in areas with moderate to high water exchange in Nova Scotia (Wildish & Peer, 1983; Wildish & Kristmanson, 1985, 1994; Wildish & Fader, 1998; Wildish *et al*.,1998), and low field densities have been correlated with low current regimes and reduced food availability. Densities of up to 220 individuals/m^2 have been recorded from the Faroese shelf (Dinesen, 1999) where maximal tidal current speed was estimated to be between 79 and 98 cm/s at two *Modiolus modiolus* sites (Nørrevang *et al*. 1994, BIOFAR Stn. 661 & 662; cited from Dinesen & Morton, 2014). Mair *et al*. (2000) also observed that in Scottish sites with *Modiolus modiolus* beds, densities were greater where there were high tidal currents.

Comely (1978) suggested that areas exposed to strong currents required an increase in byssus production, at energetic cost, and resulted in lower growth rates. At water velocities exceeding 16 cm/s in a flume tank, Carrington *et al*. (2008) observed that *Modiolus modiolus* individuals could not extend the foot beyond the shell to form and attach byssus threads. However, the mussel bed reduces water flow rates by increasing drag through friction. Carrington *et al*. (2008) observed that mussel beds of *Mytilus trossulus* and *Mytilus galloprovincialis* in laboratory and field studies were able to reduce flow rates between 0.1 and 10% of free-stream velocity. This modification of flow may enhance suspension feeding in areas of high current flow and allow byssus production to continue (Carrington *et al*., 2008).

Wildish *et al*. (2000) examined suspension feeding in *Modiolus modiolus* in a flume tank and noted that individuals kept the exhalent and inhalant siphons open over the range of flow rates studied, from 0.12-0.63 m/s. However, the inhalant siphon closed by about 20% in currents above 0.5m/s.

Fouling by epifauna and algae in the infralittoral may also decrease the population's resistance to increased water flow. Witman (1984, cited in Suchanek, 1985) found that over 11 months in New England, 84% of fouled mussels were dislodged in comparison with 0% of unfouled individuals. As the beds described by the biotope group occur in the circalittoral, algal overgrowth is not relevant, but the presence of high levels of epifauna on circalittoral beds may similarly increase dislodgement.

Changes in water flow may also be a spawning cue, although the available evidence does not strongly support this hypothesis. Schweinitz & Lutz, (1976) observed spontaneous, spawning in a group on *Modiolus modiolus* individuals kept in a tank when the water flow stopped, while previous attempts to induce spawning by various methods had failed. However, subsequent attempts to induce spawning by stopping the water flow failed (De Schweinitz & Lutz, 1976). A similar spawning response to the cessation of flow in *Mytilus edulis* (Williamson, 1997) was cited (De Schweinitz & Lutz, 1976).

Holt *et al*. (1998) suggested water movement was important in the development of dense reefs and beds of *Modiolus modiolus*. The weak to very weak tidal streams within this biotope may contribute to the lower abundances of *Modiolus modiolus*, that might suggest that the water flow conditions are not optimum within this biotope. An increase in water flow may benefit the *Modiolus modiolus* and could improve larval dispersal, food abundance and gaseous exchange rates. A decrease in water flow rate, would reduce water flow to almost nothing. As *Modiolus modiolus* survives best in conditions with higher levels of water flow, this reduction could cause a reduction in its abundance.

Evidence for the effect of changes in water flow on *Cerianthus lloydii* is unavailable. This species is recorded from biotopes with a wide range of water flow regimes. Therefore, it is likely to have a high tolerance to an increase in water flow rates. However, a decrease in the water flow rate within this biotope will create almost entirely still conditions. The effect of such low water flow rates on this species is not clear.

Sensitivity assessment. Flow rates are an important factor for *Modiolus modiolus*, which may be sensitive to both increases and decreases in flow. An increase in water flow rates within this biotope will create physical conditions more similar to those found within biotopes where *Modiolus modiolus* beds are found. This increase could create conditions that are optimum for the bivalve species, and where bed formation is viable. This would create a shift away from the biotope in consideration. However, there is no evidence available on how long this process may take, and there are no previous case studies on which to base these assumptions. A decrease in water flow is most likely to have a negative impact on this biotope, and is likely to cause issues with larval distribution for *Modiolus modiolus*, and has the potential to cause mortality of this bivalve which relies on water flow for food supply. However, at the benchmark of this pressure there is unlikely to be any change in the health of the biotope. Consequently, both the resistance and resilience have been assessed as 'High', which results in the biotope being 'Not sensitive' to this pressure at the benchmark.

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

The majority of *Modiolus modiolus* populations are subtidal and unlikely to be affected by wave action directly. However, increased wave action results in increased water flow in the shallow subtidal. Wave mediated water flow tends to be oscillatory, i.e. move back and forth (Hiscock, 1983), and may result in dislodgement or removal of individuals. *Mytilus edulis* was shown to increase byssus production in response to agitation (Young, 1985) and *Modiolus modiolus* may respond similarly. However, horse mussels attached to hard substrata are probably more intolerant of wave action than *Mytilus edulis* due to their larger size, and hence increased drag. The intolerance of semi-infaunal or infaunal populations probably owes more to the nature of the substratum rather than their attachment. Populations on mobile sediment may be removed by strong wave action due to removal or changes in the substratum. No information concerning storm damage was found. Shallow, nearshore subtidal populations in Strangford Lough were exposed to wave mediated flows of 0.1 m/s (Elsäßer et al., 2013). Decreased wave action may allow horse mussel beds to extend into shallower depths, however, the rates of increase in bed size are likely to be slow, probably much longer than the duration of the pressure at the benchmark level.

Evidence for the effect of changes in wave exposure on *Cerianthus lloydii* is unavailable.

Sensitivity assessment. No direct evidence was found to assess sensitivity to changes at the pressure benchmark within this biotope. However, due to the very slight changes in wave exposure at the benchmark the resistance and resilience of the biotope as 'High', giving a 'Not sensitive' assessment.

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.

	Resistance	Resilience	Sensitivity
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.

	Resistance	Resilience	Sensitivity
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.

	Resistance	Resilience	Sensitivity
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.

	Resistance	Resilience	Sensitivity
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**.

	Resistance	Resilience	Sensitivity
De-oxygenation	High Q: Medium A: Medium C: Medium	High Q: High A: Medium C: Medium	Not sensitive Q: Medium A: Medium C: Medium

Theede *et al.* (1969) examined the relative tolerance of gill tissue from several species of bivalve to exposure to 0.21mg/l O_2 with or without 6.67 mg of sulphide (at 10°C and 30 psu). *Modiolus modiolus* tissue was found to be the most resistant of the species studied, retaining some ciliary activity after 120 hours compared with 48 hrs for *Mytilus edulis*.

No information was available on the tolerance of *Cerianthus lloydii* to de-oxygenation.

Sensitivity assessment. While it is difficult to extrapolate from tissue resistance to whole animal resistance (taking into account behavioural adaptations such as valve closure) the evidence suggests that horse mussels are more, or at least similarly, tolerant of hypoxia and hydrogen sulphide than the blue mussel. In addition, most bivalve molluscs exhibit anaerobic metabolism to some degree. Therefore, a resistance of 'High' has been recorded at the benchmark level and resilience is assessed as 'High' (based on no effect to recover from). This biotope is therefore considered to be 'Not sensitive' at the pressure benchmark.

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

Navarro & Thompson (1996) suggested that *Modiolus modiolus* was adapted to an intermittent and often inadequate food supply. The persistence of a horse mussel population in the vicinity of a sewage sludge dumping site (Richardson *et al.*, 2001) suggests that the species is tolerant of high nutrient levels. Moderate nutrient enrichment may, therefore, be beneficial by increasing phytoplankton productivity and organic particulates, and hence food availability. However, eutrophication may have indirect adverse effects, such as increased turbidity, increased risk of deoxygenation (see above) and the risk of algal blooms. Shumway (1990) reviewed the effects of algal blooms on shellfish and reported that a bloom of *Gonyaulax tamarensis* (*Protogonyaulax*) was highly toxic to *Modiolus modiolus*. Shumway (1990) also noted that both *Mytilus* spp. and *Modiolus* spp. accumulated paralytic shellfish poisoning (PSP) toxins faster than most other species of shellfish, e.g. horse mussels retained *Gonyaulax tamarensis* toxins for up to 60 days (depending on the initial level of contamination). Landsberg (1996) also suggested that there was a correlation between the incidence of neoplasia or tumours in bivalves and out-breaks of paralytic shellfish poisoning in which bivalves accumulate toxins from algal blooms, although a direct causal effect required further research.

No information was available on the effect of nutrient enrichment on *Cerianthus lloydii*.

Sensitivity assessment. However, while algal blooms may have sublethal effects, the biotope is 'Not sensitive' at the benchmark level, which assumes compliance with environmental standards.

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

Little direct evidence was available to support the assessment of this pressure, which is largely based on expert judgement. The currents in this biotope are weak, and organic deposits will not aid the removal of and impacts may be greater. The persistence of a *Modiolus modiolus* population in the vicinity of a sewage sludge dumping site (Richardson *et al.*, 2001) suggests that the species is tolerant of high levels of organic matter. At the pressure benchmark which refers to enrichment rather than gross organic pollution (Tillin & Tyler-Walters, 2014) the extra rate of organic matter accumulation may not far exceed the natural background level, particularly in sheltered areas.

Borja *et al.*, (2000) and Gittenberger & van Loon (2011) in the development of the AZTI Marine Biotic Index (AMBI) index to assess disturbance (including organic enrichment) both assigned

Cerianthus lloydii to their Ecological Group I, 'species very sensitive to organic enrichment and present under unpolluted conditions (initial state)'. The basis for their assessment and relation to the pressure benchmark is not clear (Tillin & Tyler-Walters, 2014). However, if this evidence is found to relate to this pressure *Cerianthus lloydii* may be lost leading to a resilience of 'Medium'

Sensitivity assessment. At the pressure benchmark, which refers to enrichment rather than gross organic pollution, this biotope is considered to have 'High' resistance and hence, 'High' resilience. This biotope group is therefore considered to be 'Not Sensitive'.

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.

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

This biotope is only found in mixed sediment, and the burrowing anemone, *Cerianthus lloydii* would not be able to survive if the substratum type was changed to either a soft rock or hard artificial type. Consequently, the biotope would be lost altogether if such a change occurred.

Sensitivity assessment. The resistance to this change is 'None', and the resilience is assessed as 'Very low' due to the long-term nature of a change in substratum. The biotope is assessed to have a 'High' sensitivity to this pressure at the benchmark.

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

The change in one Folk class is considered to relate to a change in classification to adjacent categories in the modified Folk triangle (Long, 2006). For the mixed sediments that characterize this biotope the sediment changes considered may be to coarser or finer sediments. *Modiolus modiolus* are found on and in a variety of substrata ranging from fine mud with shells and gravel to bedrock. Comely, (1978) found *Modiolus modiolus* in different types of sediment at varying densities, with low densities (mean 4 individuals/ m^2) in clean gravel, stones and small boulders and at higher densities (mean 10 individuals/m^2) in fine muddy sand and silty sand with coarse gravel overlain by clean coarse sand with boulder). Based on ROV and SCUBA survey in Strangford Lough, Elsäßer *et al*. (2013) modelled suitable habitat and found that substratum type was a key predictor of distribution. The remaining *Modiolus modiolus* beds in Strangford Lough were associated with the presence of finer substrata, such as sand and mud, and negatively correlated with coarser substratum types such as bedrock, boulders and cobbles. *Cerianthus lloydii* is found within a range of biotopes with different substrata compositions from mud and muddy gravel, through to gravel and coarse sand with some pebbles (Tillin & Tyler-Walters, 2014). If each of the constituent substratum types within this biotope was to shift one grade of Folk class, it is unlikely to have a significant negative effect on this species.

Sensitivity assessment. Given the wide range of substratum types occupied by the characterizing species within this biotope, a change at the pressure benchmark is unlikely to cause a change in the health of the biological component of the biotope. Consequently, both resistance and resilience are assessed as 'High', giving the biotope an assessment of 'Not sensitive'.

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

The substratum of this biotope consists of pebbles, boulders and cobbles on mud or muddy sand (Conner *et al*., 2004). *Modiolus modiolus* are found on top of the substratum and the second characterizing species *Cerianthus lloydii* is burrows into the sediment. The process of extraction is considered to remove all biological components of the biotope group. No direct evidence for resistance and recovery to this pressure was found and the sensitivity assessment is therefore based on expert judgement.

Sensitivity assessment. Resistance is assessed as 'None' based on expert judgment but supported by the literature relating to the position of these species on or within the seabed. At the pressure benchmark the exposed sediments are considered to be suitable for recolonisation almost immediately following extraction. Recovery will be mediated by the scale of the disturbance and the suitability of the sedimentary habitat. Recovery is most likely to occur via larval recolonisation. Resilience is considered to be 'Low', and the sensitivity is assessed as 'High'.

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

As *Modiolus modiolus* are large, sessile and shallowly buried individuals are unable to escape from abrasion of the substratum and clear evidence exists for declines in the extent and density of beds exposed to activities that lead to this pressure. The associated attached epifauna and infauna are also likely to be damaged and removed by this pressure.

Evidence of long-term decline in response to abrasion pressures resulting from mobile gears has been developed from surveys and monitoring in areas where beds have been impacted. Horse mussel beds in Strangford Lough in Northern Ireland have suffered notable declines in extent. Magorrian & Service (1998) reported that queen scallop trawling resulted in flattening of horse mussel beds and disruption of clumps of horse mussels and removal of emergent epifauna in Strangford Lough. They suggested that the emergent epifauna were more intolerant than the horse mussels themselves but were able to identify different levels of impact, from impacted but largely intact to few *Modiolus modiolus* intact with lots of shell debris (Service & Magorrian 1997; Magorrian & Service 1998). Recent comparison of dive survey data sets collected in 1975-1983 and 2005-2007, demonstrated further declines in *Modiolus modiolus*, the bivalves *Aequipecten irregularis* and *Chlamys varia* and some erect sessile fauna between the survey periods (Strain *et al*., 2012). Strain *et al*. (2012) concluded that the epifaunal assemblage in Strangford Lough had shifted due to the period of intensive fishing for the queen scallop (*Aequipectin irregularis*) between

1985 and 1995. Strain *et al*., (2012) noted that although all mobile fishing gear was banned in 2004, there were no detectable differences indicating recovery in epifaunal communities between 2003 and 2007 surveys, seven years after the period of intensive fishing for queen scallops.

Cook *et al*., (2013) were able to examine the effects of a single pass by an otter trawl on *Modiolus modiolus* beds off the Lleyn Peninsula and a scallop dredge on the northeast of the Isle of Man. The tracks from the mobile gears were observed during routine bed monitoring and the observations are based on normal fishing activities rather than designed experiments. The otter trawl resulted in a 90% reduction in the number of epifauna while the scallop dredge resulted in a 59% reduction. At both sites mean *Modiolus modiolus* abundance declined, with visible flattening of clumps in response to dredging. No evidence of recovery was recorded at the Isle of Man site a year after impact was first recorded.

Kenchington *et al*. (2006) examined the effects of multiple passes of an otter trawl on benthic communities on the Western Bank on Canada's Scotian shelf in the northwest Atlantic. The community was dominated (76%) by *Modiolus modiolus* attached to rocks, embedded in the seabed or in small groups but was not considered to represent a *Modiolus modiolus* reef habitat. The transect was trawled 12 - 14 times, on three occasions over a 20 month period. As a result, the epif auna was reduced (from 90% to 77% contribution to the community). The most marked decline was in *Modiolus modiolus* abundance, which declined by approximately 80% to 60% of the community, (a reduction in biomass from 2752.9g before trawling in 1997 to 987.4g after trawling in 1999) due to direct damage from the trawl and subsequent consumption by predators and scavengers.

No direct evidence was available to assess the sensitivity *Cerianthus lloydii* to surface abrasion. However, in a meta-analysis of the effects of bottom-fishing gear on biota Kaiser *et al*. (2006) found that suspension feeders, which *Cerianthus lloydii* is, were consistently vulnerable to scallop dredging across gravel, sand and mud habitats. However, the effect of beam trawling was highly dependent on substratum type (Kaiser *et al*., 2006). Another burrowing cerianthid anemone, *Cerianthus borealis*, was found to be absent from an area heavily trawled for scallops (Langton & Robinson, 1990). The burrowing habit of *Cerianthus lloydii* would confer some protection from surface disturbance although individuals would be more exposed when close to the surface feeding. *Cerianthus lloydii* inhabits a soft tube, which can be up to 40cm long and is permanently buried. The anemone can move freely within the tube and can retract swiftly if required (Tillin & Tyler-Walters, 2014).

Sensitivity assessment. Abrasion at the surface only is considered likely to flatten clumps and dislodge and break individual *Modiolus modiolus*. Resistance of the biotope is assessed as 'Low', although the significance of the impact for the bed will depend on the spatial scale of the pressure footprint, and its frequency. Resilience is assessed as 'Low' (2-10 years), and sensitivity is assessed as 'High'. Dinmore *et al*., (2003) noted that the first pass caused the majority of damage to seabed habitats. However, this biotope is likely to be more sensitive to repeated trawling activities.

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

Penetration and or disturbance of the substratum would result in similar results as abrasion or removal of this biotope. Damage to *Cerianthus lloydii* would be greater within this pressure, as their ability to retract within their tubes would be limited.

Sensitivity assessment. Resistance of the biotope is assessed as ‘Low’, although the significance of the impact for the bed will depend on the spatial scale of the pressure footprint. Resilience is assessed as ‘Low’, and sensitivity is assessed as ‘High’.

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

Changes in light penetration or attenuation associated with this pressure are not relevant to *Modiolus modiolus* biotopes. However, alterations in the availability of food or the energetic costs in obtaining food or changes in scour could either increase or decrease habitat suitability for *Modiolus modiolus* beds. *Modiolus modiolus* is found in a variety of turbid and clear water conditions (Holt *et al*., 1998). Muschenheim & Milligan (1998) noted that the height of the horse mussel beds in the Bay of Fundy positioned them within the region of high quality seston while avoiding high levels of re-suspended inorganic particulates (2.5-1500mg/l) at the benthic boundary layer. Decreases in turbidity may increase phytoplankton productivity and potentially increase food availability. Therefore, horse mussel beds may benefit from reduced turbidity.

No evidence on the effect of a change in turbidity on *Ceriathus lloydii* could be found.

Sensitivity assessment. Insufficient evidence was found to assess this pressure. Resistance to this pressure is assessed as 'High' as an increase in turbidity may impact feeding and growth rates but not result in mortality of adults. Resilience is assessed as 'High' be default and the biotope is assessed as 'Not Sensitive' to changes in turbidity at the benchmark level.

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

Mass Accumulation Rates of 0.63±0.09 g cm$^{2/}$year) following bottom trawling in Strangford Lough were suggested to act as a driver for potential negative effects on the physiological condition of remnant populations of *Modiolus modiolus* by Strong & Service (2008). In a series of burial experiments, Hutchison *et al.* (2016) tested the response of individuals to burial under three depths of sediment (2, 5 and 7 cm), three sediment fractions (coarse-1-2 mm; medium-fine-0.25-0.95 mm and fine-0.1-0.25 mm) and five burial durations (2, 4, 8, 16, 32 days). *Modiolus modiolus* could not re-emerge from sediments and mortality increased with duration of smothering and the proportion of fine particles in the smothering material, the depth of burial did not alter mortality rates. Buried individuals survived for 8 days without apparent mortality but by 16 days, cumulative mortality was greater than 50% (Hutchison *et al.*, 2016).

Cerianthids require open tubes as they breathe with their entire body surface (Schäfer, 1972). In normal accretion, *Cerianthus lloydii* keeps pace with the accretion and, as a result, develops burrows much larger than the animal itself (Schäfer, 1972; Bromley, 2012). Schäfer (1972) reported that an increase in depositional rate led to an avoidance behaviour in *Cerianthus lloydii*. The organism ceases tube building activity and instead the animal bunches its tentacles and intrudes its way up to the new surface, where it establishes a new burrow. No information on the depth of material through which is can burrow was given but *Cerianthus lloydii* can grow to 15 cm in length and burrows can be up to 40 cm long. No information on the burrowing holothurians was fond.

Sensitivity assessment. The experiments by Hutchison *et al.* (2016) show that duration of burial is a key factor determining survival in *Modiolus modiolus*. Burial under even small amounts of fine sediment (2 cm) for longer than 8 days could lead to significant mortality. Site-specific hydrodynamics that influence the mobility of deposited sediments will mediate resistance. This biotope occurs in low energy conditions (wave sheltered with weak to negligible flow) so that a fine sediment deposit is likely to persist.

Large holothurians and *Cerianthus lloydii* could probably resurface through a deposit of 5 cm but even 2 cm of sediment may cause significant mortality in the *Modiolus modiolus* population as they sit on or in the surface of the sediment and the deposit would probably remain for over a week. Although some *Modiolus* on the upper faces of boulders may survive a deposit of 5 cm, a resistance of ‘Low’ is suggested due to the potential loss of a significant proportion the *Modiolus modiolus*. Resilience is assessed as 'Low' and sensitivity is, therefore, assessed as 'High'.

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

Mass Accumulation Rates of 0.63±0.09 g cm$^{2/}$year) following bottom trawling in Strangford Lough were suggested to act as a driver for potential negative effects on the physiological condition of remnant populations of *Modiolus modiolus* by Strong & Service (2008). In a series of burial experiments, Hutchison *et al.* (2016) tested the response of individuals to burial under three depths of sediment (2, 5 and 7 cm), three sediment fractions (coarse-1-2 mm; medium-fine-0.25-0.95 mm and fine-0.1-0.25 mm) and five burial durations (2, 4, 8, 16, 32 days). *Modiolus modiolus* could not re-emerge from sediments and mortality increased with duration of smothering and the proportion of fine particles in the smothering material, the depth of burial did not alter mortality rates. Buried individuals survived for 8 days without apparent mortality but by 16 days, cumulative mortality was greater than 50% (Hutchison *et al.*, 2016).

Cerianthids require open tubes as they breathe with their entire body surface (Schäfer, 1972). In normal accretion, *Cerianthus lloydii* keeps pace with the accretion and, as a result, develops burrows much larger than the animal itself (Schäfer, 1972; Bromley, 2012). Schäfer (1972) reported that an increase in depositional rate led to an avoidance behaviour in *Cerianthus lloydii*. The organism ceases tube building activity and instead the animal bunches its tentacles and intrudes its way up to the new surface, where it establishes a new burrow. No information on the depth of material through which is can burrow was given but *Cerianthus lloydii* can grow to 15 cm in length and burrows can be up to 40 cm long. No information on the burrowing holothurians was fond.

Sensitivity assessment. The experiments by Hutchison *et al.* (2016) show that duration of burial is a key factor determining survival in *Modiolus modiolus*. Burial under even small amounts of fine sediment (2 cm) for longer than 8 days could lead to significant mortality. Site-specific hydrodynamics that influence the mobility of deposited sediments will mediate resistance. This biotope occurs in low energy conditions (wave sheltered with weak to negligible flow) so that a fine sediment deposit is likely to persist.

The deposition of 30 cm of fine sediment is may affect the community adversely. *Cerianthus lloydii* and large holothurians can burrow and move into and out of their own burrows. It is probable, therefore, that deposition of 30 cm of fine sediment will have little effect other than to suspend feeding temporarily and the energetic cost of burrowing. But even 2 cm of sediment may cause significant mortality in the *Modiolus modiolus* population as they sit on or in the surface of the sediment and the deposit would probably remain for over a week. Therefore, a resistance of ‘Low’ is suggested due to the potential loss of a significant proportion the *Modiolus modiolus*. Resilience is assessed as 'Low' and sensitivity is, therefore, 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	Not relevant (NR) 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

Modiolus modiolus habitat restoration projects may translocate stock to re-populate areas of suitable habitat (Elsässer *et al*., 2013). No evidence was found for detrimental effects arising from this practice, although there is potential for the movement of pathogens and non-indigenous invasive species. No evidence was available on the effect of this pressure on *Cerianthus lloydii.*

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

No evidence.

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

Brown & Seed (1977) reported a low level of infestation (ca 2%) with pea crabs *Pinnotheres* sp. in Port Erin, Isle of Man and Strangford Lough. Comely (1978) reported that ca 20% of older specimens, in an ageing population, were damaged or shells malformed by the boring sponge *Cliona celata*. Infestation by the boring sponge reduces the strength of the shell and may render the population less resistant of physical disturbance (see above). However, little other information concerning the effects of parasites or disease on the condition of horse mussels was found.

Shumway (1990) reviewed the effects of algal blooms on shellfish and reported that a bloom of *Gonyaulax tamarensis* (*Protogonyaulax*) was highly toxic to *Modiolus modiolus*. Shumway (1990) also noted that both *Mytilus* spp. and *Modiolus* spp. accumulated paralytic shellfish poisoning (PSP) toxins faster than most other species of shellfish, e.g. horse mussels retained *Gonyaulax tamarensis t*oxins for up to 60 days (depending on the initial level of contamination). Landsberg (1996) also suggested that there was a correlation between the incidence of neoplasia or tumours in bivalves and out-breaks of paralytic shellfish poisoning in which bivalves accumulate toxins from algal blooms, although a direct causal effect required further research.

The parasites *Martelia refringens* or other *Marteilia* sp. can cause significant bivalve infections. Although these have been reported to infect *Modiolus modiolus* (Bower *et al*. 2004) no evidence was available to assess the scale of impact. No evidence was available on the effect of microbial pathogens on *Cerianthus lloydii.*

Sensitivity assessment. There was insufficient to assess the effect of this pressure on the biotope.

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

Artisanal fisheries have targeted *Modiolus modiolus* as bait for the long-line fishery (Jeffreys 1863; Wiborg 1946) and, more locally, for human consumption around the British Isles (Jeffreys 1863; Holt *et al*. 1998) and the Faroe Islands (Dinesen & Ockelmann 2005). While removal of targeted species, such as scallops, will reduce species richness the loss of targeted species is unlikely to adversely affect the *Modiolus modiolu*s bed through biological effects. The physical effects of dredging for scallops and other targeted species are discussed under abrasion and penetration pressures. The removal of target species that predate on *Modiolus modiolus* would potentially be beneficial allowing the recruitment of juveniles to the adult population. However, such effects are not directly documented and could not be included within the assessment.

No evidence was available for the effect of this pressure on *Cerianthus lloydii.*

Sensitivity assessment. Neither of the characterizing species within this biotope are currently directly targeted in the UK and hence this pressure is considered to be 'Not relevant'.

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

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The damage and loss of *Modiolus modiolus* beds and reefs has been associated with past scallop dredging in Strangford Lough and around the Isle of Man (add refs), and numerous authors consider them to be at risk of damage form bottom trawling (add refs) (see abrasion and penetration pressures above). The incidental removal of *Modiolus modiolus* other associated species from this biotope as by-catch when other species are being targeted 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 '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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