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Lagis koreni and *Phaxas pellucidus* in circalittoral sandy mud

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

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2016-06-19

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

Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [https://www.marlin.ac.uk/habitats/detail/1095]. All terms and the MarESA methodology are outlined on the website (https://www.marlin.ac.uk)

This review can be cited as:
De-Bastos, E.S.R. 2016. [Lagis koreni] and [Phaxas pellucidus] in circalittoral sandy mud. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom.
DOI https://dx.doi.org/10.17031/marlinhab.1095.1

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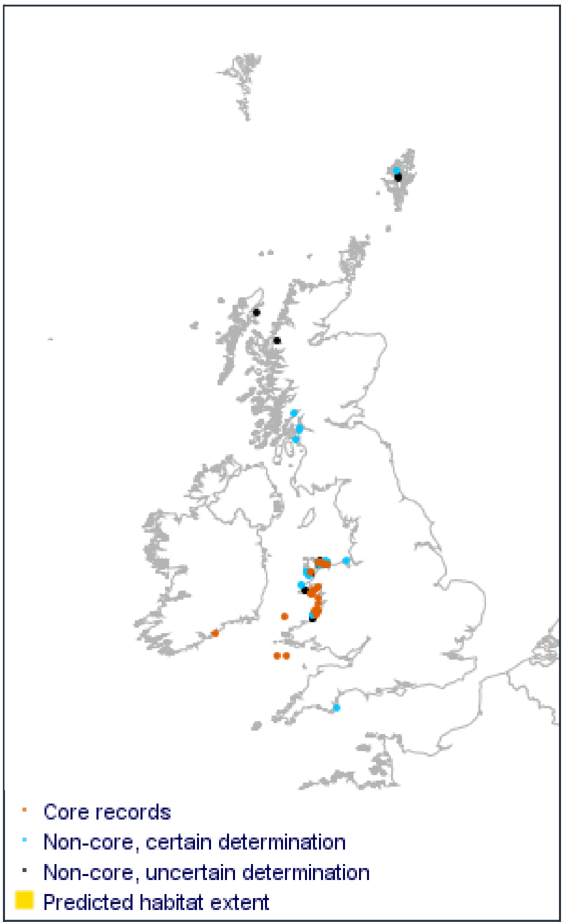
***Lagis koreni* and *Phaxas pellucidus* in circalittoral sandy mud**
Photographer: Keith Hiscock



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

Researched by Eliane De-Bastos **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A5.355	*Lagis koreni* and *Phaxas pellucidus* in circalittoral sandy mud
JNCC 2015	SS.SMu.CSaMu.LkorPpel	*Lagis koreni* and *Phaxas pellucidus* in circalittoral sandy mud
JNCC 2004	SS.SMu.CSaMu.LkorPpel	*Lagis koreni* and *Phaxas pellucidus* in circalittoral sandy mud
1997 Biotope		

Description

In stable circalittoral sandy mud dense populations of the tube building polychaete *Lagis koreni* may occur. Other species found in this habitat typically include bivalves such as *Phaxas pellucidus*, *Kurtiella bidentata* (syn. *Mysella bidentata*) and *Abra alba* and polychaetes such as *Mediomastus* *fragilis*, *Spiophanes bombyx*, *Owenia fusiformis* and *Scalibregma inflatum*. At the sediment surface, easily visible fauna include *Lagis koreni* and *Ophiura ophiura*. *Lagis koreni* is an important source of food for commercially important demersal fish, especially dab and plaice (Macer, 1967; Lockwood, 1980; Basimi & Grove, 1985). (Information taken from Connor *et al.*, 2004).

Depth range

10-20 m, 20-30 m, 30-50 m, 50-100 m

Additional information

-

Listed By

- none -

Further information sources

Search on:

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Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

SS.SMu.CSaMu.LkorPpel is a stable circalittoral biotope which occurs in full salinity conditions, on exposed and moderately exposed environments experiencing strong, moderately strong, weak and very weak tidal streams (Connor *et al*., 2004). This hydrographic regime allows for the development of sandy muds that support dense populations of the tube building polychaete *Lagis koreni*, and typically include bivalve *Phaxas pellucidus.* The biotope is diverse and supports a number of other polychaetes and bivalve species, as well as mobile macrofauna including echinoderms, crabs and fish. These species contribute to species richness and diversity but are not considered important characterizing, defining, or structuring species. *Lagis koreni* and *Phaxas pellucidus* identify the biotope and are therefore the focus of this assessment. More information on the remaining species can be found in other biotope assessments available on this website. *Lagis koreni* is an important source of food for commercially important demersal fish, especially dab and plaice (Macer, 1967; Lockwood, 1980; Basimi & Grove, 1985), so this relationship will be addressed in assessments where disturbance may affect predation rates in the biotope.

In some areas e.g. Liverpool Bay, SS.SMu.CSaMu.LkorPpel and SS.SSa.CMuSa.AalbNuc have exhibited cyclical behaviour with the community periodically switching from one biotope to another (Rees *et al*., 1992). It is likely that the two biotopes are merely different aspects of the same community as *Lagis koreni* is often recorded with high densities of *Abra alba* (Eagle, 1975; Rees & Walker, 1983).

Resilience and recovery rates of habitat

Lagis koreni is a small to medium-sized polychaete worm that lives in an elongated conical sand tube of 2-5 cm length in sand and muddy sand, feeding head down on detrital material in the sediments (Mayhew, 2007). There is some variation in the reports of longevity and breeding of *Lagis koreni*, but it is thought to live between 1 and 2 years, reaching maturity at one year of age with animals breeding once and then dying (Fish & Fish, 1996), which agrees with reports of a lifespan of 15-18 months suggested by Irlinger *et al.* (1991). Nichols (1977, cited in Rees & Dare, 1993) noted an early and late summer recruitment in Kiel Bay but with additional sporadic recruitment occurring through most of the year. Comparable events were recorded by Elkaim & Irlinger (1987, cited in Rees & Dare, 1993) in Seine Bay, France, with one or two recruitment periods, depending on year and location. Nicolaidou (1983) observed only one recruitment (in June) off the north Wales coast, UK. Animals have survived 2.5 years in laboratory conditions (Nicolaidou, 1983). The sexes are separate and fertilization occurs externally in the water column. The larvae are planktotrophic and settle after a period of about 2 months in the plankton. Dense communities of *Lagis koreni* are found on the seabed, and it is likely that this species has a relatively high recolonization rate. Growth has been reported as fast initially during the warm summer months (Nicolaidou, 1983). The species has a high fecundity with significant juvenile mortalities and high growth rates (Irlinger *et al*., 1991). The species has the capacity to resettle in more suitable substrata before final settlement. Adult density is likely to influence habitat choice of new recruits, as the presence of conspecific adults induced the high resuspension rate of the post-larvae (Olivier *et al*., 1996).

Phaxas pellucidus is a slender razor shell up to 4 cm long (Neish, 2008). It is small to medium in size and an infaunal burrower with fragile shell. The recovery potential of *Phaxas pellucidus* is difficult to judge as no information on reproduction or longevity was found in the literature. Other members of the Pharidae, the razor shells, are long-lived and reach sexual maturity after 3-5 years. *Phaxas pellucidus* can be locally abundant and can dominate disturbed sediments suggesting that it has some opportunistic traits (Rees *et al.*, 1992). The planktonic larvae are found in the water column in autumn and winter (Lebour, 1938), which suggests that wide spatial dissemination is possible for this species.

Resilience assessment: Recovery of habitats following a disturbance is dependent on physical, chemical and biological processes and can be a more rapid process than in other areas (Bishop *et al.*, 2006; cited in Fletcher *et al.*, 2011). However, recovery times after physical disturbance have been found to vary for different sediment types (Roberts *et al.*, 2010). Dernie *et al.* (2003) found that muddy sand habitats had the longest recovery times, compared to mud and clean sand habitats. Population recovery rates will be species specific. Removal of the characterizing species *Lagis koreni* and *Phaxas pellucidus* would result in the biotope being lost and/or reclassified. The evidence presented suggests that *Lagis koreni* is short lived, reaches maturity within one year, is capable of rapid recolonization through larval recruitment following disturbance events, and reaches former densities within a year (e.g. Arntz & Rumohr, 1986). However, *Phaxas pellucidus* is likely to be long lived and takes several years to reach maturity. Therefore, the time for the overall SS.SMu.CSaMu.LkorPpel community to reach maturity also likely to be several years. Thus, where the biotope has Medium resistance to a disturbance, resilience is likely to be **High,** given that the majority of the important characteristic species of the biotope can maintain the character of the biotope and recruit within the first two years after disturbance. However, while *Lagis koreni* may recolonize the area within two years after the loss of a significant proportion of the community (resistance is Low or None), *Phaxas pellucidus* may only recolonize the area in up to five years. Therefore, the biotope may take longer to return to original species diversity and abundance and resilience is likely to be **Medium** (2-10 years). The resilience is based of life history traits rather than direct evidence so that the confidence is Low.

NB: The resilience and the ability to recover from human induced pressures is a combination of the environmental conditions of the site, the frequency (repeated disturbances versus a one-off event) and the intensity of the disturbance. Recovery of impacted populations will always be mediated by stochastic events and processes acting over different scales including, but not limited to, local habitat conditions, further impacts and processes such as larval-supply and recruitment between populations. Full recovery is defined as the return to the state of the habitat that existed prior to impact. This does not necessarily mean that every component species has returned to its prior condition, abundance or extent but that the relevant functional components are present and the habitat is structurally and functionally recognizable as the initial habitat of interest. It should be noted that the recovery rates are only indicative of the recovery potential.

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	Medium Q: Medium A: Medium C: High	High Q: Low A: NR C: NR	Low Q: Low A: NR C: NR

Lagis koreni is widely distributed, found from the Artic and north-east Europe to the Adriatic. *Phaxas pellucidus* is widespread, often abundant around Britain and distributed from Norway to north-west Africa (Hayward & Ryland, 1995b).

Feeding rates of *Lagis koreni* have been reported to be influenced by temperature (Nicolaidou, 1983, 1988). However, the range of temperatures investigated in Nicolaidou (1988) varied from 7-15°C, and are not conclusive regarding the possible behaviour of *Lagis koreni* in response to increases in temperature. Furthermore, Schückel *et al.* (2010) investigated the temporal variability of macrofauna communities in the northern North Sea in relation to changes in temperature and/or changes in hydrography. The authors observed a significant negative correlation between total macrofaunal abundance, including of *Lagis koreni*, and mean surface temperature (SST). Mean surface temperatures recorded varied between 13.4-16.6°C. Mean bottom temperatures remained more stable and varied between 6.7-7.6°C. The authors observed a strong decrease in mean abundance as a result of increased SST because increased SST mainly enhanced stratification and contributed to a decrease in food availability for the benthic community at the site.

Populations of the razor shell *Ensis siliqua* in the warmer waters of Portugal spawn several months earlier in the year than UK populations and are sexually mature at only one year old (Gaspar & Monteiro, 1998; Henderson & Richardson, 1994) compared to three in the UK (Hill, 2006). Recruitment of *Phaxas pellucidus* may therefore be affected by an increase in temperature.

Some protection may be afforded by the infaunal position of the characterizing species, as these are not subjected to the large temperature variations and may be less resistant to changes, leading to a decline in species diversity. Temperature may also affect microbial activity within the sediment which could alter the depth at which the anoxic layer appears.

Sensitivity assessment. No direct evidence concerning temperature tolerances of the biotope and the characterizing species was found. The characterizing species of the biotope are widely distributed and likely to occur both north and south of the British Isles, where typical surface water temperatures vary seasonally from 4-19°C (Huthnance, 2010), and maximum sea surface temperatures rarely exceed 20°C (Hiscock, 1998). Elevated temperatures may affect growth of some of the characterizing species but no mortality is expected. It is therefore likely that *Lagis koreni* and *Phaxas pellucidus* are able to resist a long-term increase in temperature of 2°C, and potentially benefit from increased feeding activity and recruitment opportunities. However, based on Schückel *et al.* (2010), an acute 5°C increase for one month period may result in some mortality, so resistance is therefore assessed as **Medium** (loss <25%). Resilience is likely to be **High** so the biotope is considered to have **Low** sensitivity to an increase in temperature at the pressure benchmark level.

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

Lagis koreni is widely distributed, found from the Artic and north-east Europe to the Adriatic. *Phaxas pellucidus* is widespread, often abundant around Britain and distributed from Norway to north-west Africa (Hayward & Ryland, 1995b).

Growth, survivorship, reproduction and productivity of a *Lagis koreni* (studied as *Pectinaria (Lagis) koreni)* population was studied in Colwyn Bay, Wales. Growth was fast initially but it ceased completely during the winter, probably due to low temperatures (Nicolaidou, 1983). Studies by Irlinger *et al.* (1991) of the Bay of Seine macrobenthic community, France, equally reported *Lagis koreni* densities to vary throughout the year, with severe decrease in abundance at the end of winter from populations with more than 2000 individuals /m^2 after spring recruitment. Both these reports agree with Arntz & Romohr (1986), who reported Baltic populations of the species were sensitive to extremely low bottom temperature. Furthermore, feeding rates of *Lagis koreni* were reported to be influenced by temperature (Nicolaidou, 1983, 1988). Nicolaidou (1988) found that the animals were most active at higher temperatures. At 7°C the rate of sediment reworking was significantly less than that at 10 and 15°C, with some worms completely ceasing their reworking activity at 7°C (Nicolaidou, 1988).

Reiss *et al.* (2006) studied cold winter effects on benthic communities in the North Sea. In 1995/1996 mean sea surface temperature was more than 2°C below average. The authors observed that nearshore communities changed dramatically while offshore benthic communities changed more gradually. *Lagis koreni* seemed to have been one of the species to have benefited from the adverse conditions as, probably due to its opportunistic life style, the species was able to very quickly become one of the dominant species at sites affected by cold winters (Reiss *et al.*, 2006). These results agree with those of Kröncke *et al.* (2013a), who also reported *Lagis koreni* as dominating macrofauna communities following mortality of macrofauna species during and after the cold winters of 1978/1979 and 1995/96 that affected species biomass and abundance in the study area (the southern North Sea), including *Ensis* spp., which are related to characterizing species in this biotope. However, no direct evidence of tolerance of this *Phaxas pellucidus* was found.

Temperature may also affect microbial activity within the sediment which could alter the depth at which the anoxic layer appears.

Sensitivity assessment. The important characterizing species of the biotope are widely distributed and likely to occur both north and south of the British Isles, where typical surface water temperatures vary seasonally from 4-19°C (Huthnance, 2010). However, reduced temperatures may affect growth and result in some mortality of the characterizing species, based on Kröncke *et al.* (2013a) who reported mortality at 2°C anomalies below normal in sea surface temperature. Resistance is therefore assessed as **Low** (loss 25-75%). Resilience is likely to be **Medium,** so the biotope is considered to have **Medium** sensitivity to a decrease in temperature at the pressure benchmark level.

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

The biotope is only recorded in fully marine conditions (Connor *et al.*, 2004) and no records of the biotope or characterizing species occurring in hypersaline conditions was found. Furthermore, salt is used as a method of dislodging *Ensis* spp. from their burrows (Hill, 2006), suggesting that the species is sensitive to perturbations such as increased salinity. It is therefore likely that *Phaxas pellucidus* would also be sensitive.

Sensitivity assessment. No direct evidence was found on the resistance of the characterizing species to increased salinity. Long-term changes in salinity are likely to result in the loss of some species, and also result in decrease of species richness. For example, in a review of the impacts of desalination plant discharges on the marine environment, Roberts *et al.* (2010b) reported changes in infaunal community structures (including reduced abundance and diversity of polychaetes and molluscs) within close proximity from discharge areas, with aggravated impacts in poorly flushed sites. Resistance of the biotope is assessed as **Low** and resilience as **Medium**. The biotope is therefore considered to have **Medium** sensitivity to increases in salinity at the pressure benchmark level.

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

Darr *et al.* (2014) investigated the functional changes in benthic communities along a salinity gradient in the Baltic Sea, where mean salinities were 22, 12 and 8 psu at each of the study sites. *Lagis koreni* was reported to be amongst the ten most abundant species at the two sites experiencing higher salinities, but not at the site with the lowest salinity. It is not clear whether the species was totally absent from the site where mean salinity of 8 psu occurred, but it is possible to conclude that the species is likely to have experienced a major decline as a result of decreased salinity. These results agree with those of Gogina *et al.* (2010) and Gogina *et al.* (2014) who reported *Lagis koreni* occurring in the Baltic Sea at near-bottom salinities of 15-20 and 13-22 psu, respectively.

No direct evidence was found to assess the resistance of *Phaxas pellucidus* to changes in salinity. However, *Ensis ensis*, also a species of razor shell, does not occur in water of reduced salinity, although its absence from estuaries may sometimes be due to the lack of sediments of suitable grade (Holme, 1954). Furthermore, *Ensis ensis* concentrates K and Ca (Kinne, 1971b) and may be able to resist a degree of salinity reduction given that it may be subject to periodic precipitation in the intertidal. However, Darriba & Miranda (2005) concluded that salinity decreases interrupted gonadal development in the razor clam *Ensis magnus*.

Rees *et al.* (1992) reported that the biotopes SS.SSa.CMuSa.AalbNuc and SS.SMu.CSaMu.LkorPpel displayed cyclical behaviour in the Liverpool Bay area, with the community periodically switching from one biotope to the other in areas where variable salinities may occur.

Sensitivity assessment. The evidence suggests that *Lagis koreni* is likely to survive reduced salinities (18-30 psu), but is not clear regarding *Phaxas pellucidus*. However, the biotope is only recorded in fully marine conditions (Connor *et al.*, 2004), so the species are unlikely to experience hyposaline conditions and hence unlikely adapted to resist reduced salinity. A reduction in salinity from full to reduced will probably reduce species diversity of result in a change in the community and, hence, the biotope. Resistance of the biotope is therefore assessed as **Low** but with low confidence. Resilience is likely to be **Medium**, and the biotope is considered to have **Medium** sensitivity to decreases in salinity at the pressure benchmark level.

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

The hydrographic regime, including flow rates, is an important structuring factor in sedimentary habitats. For example, Irlinger *et al.* (1991) noted that the strong tidal currents that occur in the English Channel limit the occurrence of muddy fine sands, and consequently *Lagis koreni* communities to sheltered areas, which suggests this species distribution is limited to areas where substrata present are suitable to support tube building activities. The most damaging effect of increased flow rate would be the erosion of the substratum as this could eventually lead to loss of the habitat. Increased water flow rates are likely to change the sediment characteristics in which the species live, primarily by resuspending and preventing deposition of finer particles (Hiscock, 1983). This may be particularly relevant for tube building species occurring in the biotope such as characterizing species *Lagis koreni*. Furthermore, increased water flow rate may prevent settlement of larvae and therefore reduce recruitment. Olivier *et al.* (1996) noted that *Lagis koreni* (studied *as Pectinaria koreni*) purposefully selected habitats for settlement with lower densities of conspecific adults, relying on currents to reposition onto suitable substrata. Mature adults buried at depth are likely to be unaffected as muddy substrata are particularly cohesive.

Decreased water movement would result in increased deposition of suspended sediment (Hiscock, 1983). An increased rate of siltation resulting from a decrease in water flow may result in an increase in food availability for the characterizing species and therefore growth and reproduction may be enhanced, but only if food was previously limiting.

Phaxas pellucidus is recorded from moderately strong to very weak (negligible - 1.5 m/s) tidal streams (Connor *et al.*, 2004).

Sensitivity assessment. Sand particles are most easily eroded and likely to be eroded at about 0.20 m/s (based on Hjulström-Sundborg diagram, Sundborg, 1956). Furthermore, a change in water flow could potentially change the sediment type given that the cohesive nature of muddy sediments is likely to be lessened in this biotope due to its high sand content (approx. 50%, Connor *et al.*, 2004) and due to the instability resulting from feeding and sediment reworking activities of *Lagis koreni* (Eagle, 1975; Rees *et al.*, 1975, both cited in Rees & Dare, 1993). However, the biotope occurs in sandy muds in strong, moderately strong, weak and very weak tidal steams (Connor *et al.*, 2004), and a change at the benchmark level of 0.1-0.2 m/s is likely to fall within the range experienced by the biotope. Resistance and resilience are therefore considered to be **High** and the biotope is assessed as **Not Sensitive** to a change in water flow rate at the pressure benchmark level.

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

SS.SMu.CSaMu.LkorPpel is a circalittoral biotope (Connor *et al.*, 2004). Changes in emergence are **Not Relevant** to biotopes which are restricted to fully subtidal/circalittoral conditions. The pressure benchmark is relevant only to littoral and shallow sublittoral fringe biotopes.

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

Potentially, the most damaging effect of increased wave heights would be the erosion of the fine sediment substratum as this could eventually lead to loss of the habitat that characterizes the biotope. Decreased exposure will probably lead to increased siltation and reduced grain size (to muddy sediment). Changes in wave exposure may therefore influence the supply of particulate matter for tube building and feeding activities of the characterizing species. Food supplies may also be reduced affecting growth and fecundity of the species. Strong wave action may cause damage or withdrawal of the siphons and delicate feeding structures, resulting in loss of feeding opportunities and compromised growth for the characterizing species. Additionally, individuals may be dislodged by scouring from sand and gravel mobilized by increased wave action.

In a study of the life history of *Lagis koreni* (studied as *Pectinaria koreni*) in Colwyn Bay, the author reported using samples of a nearby population which had supposedly settled at the same time, with reduced wave action being suggested as a possible reason to explain the length of survival difference between the two communities (Nicolaidou, 1983). Furthermore, the author reported that growth of the species ceased completely during the winter, probably due to disturbance by storms, as well as temperature (Nicolaidou, 1983). Similarly, the species has been considered vulnerable to storm-induced sediment disturbance (Rees & Dare, 1993), and strandings have been reported following storms (Rees *et al.*, 1977; Fish & Fish, 1996)

Razor shells seem to be absent on exposed beaches where the sand is continually churned by waves. Rees *et al.* (1976) reported that wave scour caused by winter gales may have caused some individuals of *Ensis ensis* to be washed out along the north Wales coast. Therefore, an increase in wave exposure may remove some individuals of *Phaxas pellucidus* in a population.

Sensitivity assessment. Records indicate that the biotope occurs in a range of wave exposures, including exposed and moderately wave exposed conditions (Connor *et al.*, 2004). However, wave action reduces with depth, and the biotope occurs below 10 m where wave mediated flow will be reduced. Although the evidence suggests that the characterizing species are excluded from areas of intense disturbance and are likely to be dislodged by increased disturbance, a change in wave height at the pressure benchmark (change in nearshore significant wave height >3% but <5%) is unlikely to be significant. Resistance and resilience are therefore assessed as **High**, and the biotope is considered **Not Sensitive** at the benchmark level.

Chemical Pressures

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

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

There is little or no information on the resistance of the key species in the biotope. Experimental studies with various species suggest that polychaete worms are quite tolerant of heavy metals, whereas metal-contaminated sediments can exert a toxic effect on burrowing bivalves and echinoderms, especially at larval stages (Bryan, 1984). Possible suggested effects of this toxicity were reduced growth, abundance and abnormalities in areas of heavy pollution. Kanakaraju *et al.* (2008) found that, of the heavy metal contents analysed (Pb, Fe, Zn, Cu, Cd and Mn), razor clams of the *Solen* spp. in Malasya concentrated higher levels of Fe and Zn in their tissues, and Pb and Mn in their shells. These results suggest that razor clams potentially are likely to bioaccumulate toxic heavy-metals from their environment, but no biological effects of this bioaccumulation were suggested.

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.

Invertebrate communities respond to severe chronic oil pollution in much the same way. Initial massive mortality and lowered community diversity is followed by extreme fluctuations in populations of opportunistic mobile and sessile fauna (Suchanek, 1993). Oscillations in population numbers slowly dampen over time and diversity slowly increases to original levels. Infaunal communities, such as those characterizing this biotope are highly likely to be adversely affected by an event of oil pollution, but the biological effects of accumulation of PAHs are likely to depend on the length of time exposed (Viñas *et al.*, 2009). Sub-lethal concentrations may produce substantially reduced feeding rates and/or food detection ability, probably due to ciliary inhibition. Respiration rates may increase at low concentrations and decrease at high concentrations.

Ensis ensis suffered mass mortality after the *Torrey Canyon* and *Amoco Cadiz* oil spills (Southward & Southward, 1978; Southward, 1978; Cabioch *et al*., 1978). *Ensis ensis* is also reported to bioconcentrate aromatics and is highly likely to be sensitive to hydrocarbons. Four days after the *Sea Empress* oil spill, moribund razor shells (mostly *Ensis siliqua*) were the first organisms observed to have been affected (SEEEC, 1998). Glegg & Rowland (1996) observed dead razor shells washed up on the shore a few days after the final break-up of the *Braer* wreck. These reports suggest razor shells, such as *Phaxas pellucidus* have low resistance to oil pollution.

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.

High levels of mortality of *Ensis* spp. resulted from the use of dispersants following the *Torrey Canyon* oil spill (Smith, 1968). Almost complete mortality of razor shells was found at stations more than a kilometre from the shore at a depth of about 20 m, suggesting *Phaxas pellucidus* may be vulnerable. Polychaete worms, such as *Lagis koreni* are generally more resistant of a range of marine pollutants so a change in the faunal composition may be expected if chemical pollution increases. Polluted areas would be characterized by biotopes with lower species diversity and a higher abundance and density of pollution resistant species such as polychaetes.

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 is available on which to assess this pressure.

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: High	Medium Q: Low A: NR C: NR	Medium Q: Low A: NR C: NR

A number of animals have behavioural strategies to survive periodic events of reduced dissolved oxygen. These include shell closure and reduced metabolic rate in bivalve molluscs and either decreased burrowing depth or emergence from burrows for sediment dwelling crustaceans, molluscs and annelids. Furthermore, oxygen-deficient marine areas are characterized by a decline in the number and diversity of species.

In experiments with natural sediments, many infaunal species leave the sediment at oxygen concentrations below ca 1 mg/l (12% saturation). After several days at that concentration, the polychaete *Lagis koreni* (studied as *Pectinaria koreni*) emerged from the sediment with its tube. Later the tube fell over and the worm died (Diaz & Rosenberg, 1995). These results agree with reports of high mortality associated with periodic oxygen deficiency of bottom waters of Kiel Bay (e.g. Nivhols, 1977); the mortality at some, but not all, stations in the German Bight following a period of hypoxia (that lasted over than one month and oxygen concentrations were as low as 1 mg/l) (Niermann *et al.*, 1990); and reports that the species may favour organic enrichment but is displaced in anoxic sediments (e.g. Pearson & Rosenberg, 1978). Finally, a review of the thresholds of hypoxia for marine biodiversity by Vaquer-Sunyer & Duarte (2008) supports the evidence that the sub-lethal oxygen threshold for *Lagis koreni* (studies as *Pectinaria koreni*) was 1 mg/l (Nilsson & Rosenberg, 1994 cited in Vaquer-Sunyer & Duarte, 2008).

Phaxas pellucidus was absent during the period of stagnation influenced by the severe oxygen depletions in the water column in the northern Adriatic Sea (Nerlović *et al.*, 2011). Rosenberg *et al.* (1991) exposed benthic species from the NE Atlantic to oxygen concentrations of around 1 mg/l for several weeks, including species of small bivalves. After 11 days in hypoxic conditions, bivalve individuals were still alive, although individuals stretched their syphons out of the sediment.

Sensitivity assessment. Cole *et al.* (1999) suggest possible adverse effects on marine species below 4 mg/l and probable adverse effects below 2 mg/l. Different species in the biotope will have varying responses to deoxygenation. Based on the evidence presented, a decrease in oxygenation at the pressure benchmark level is likely to result in significant (25-75%) mortality of the characterizing species of this biotope. With the loss of these species, the biotope would likely be lost. Community composition would likely become dominated by fewer species that are resistant of hypoxic conditions, such as some polychaete worms, so that the overall species richness would decline significantly. Resistance is therefore assessed as **Low** and resilience as **Medium,** and the biotope is judged as having **Medium** sensitivity to exposure to dissolved oxygen concentration of less than or equal to 2 mg/l for 1 week.

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

Increased nutrients are most likely to affect abundance of phytoplankton, which may include toxic algae (OSPAR, 2009). This primary effect resulting from elevated nutrients will impact upon other biological elements or features (e.g. toxins produced by phytoplankton blooms or deoxygenation of sediments) and may lead to 'undesirable disturbance' to the structure and functioning of the ecosystem. With enhanced primary productivity in the water column, organic detritus that falls to the seabed may also be enhanced, which may be utilized by the deposit feeders in the community.

Sensitivity assessment. The community, and hence the biotope, may change to one dominated by nutrient enrichment resistant species, in particular polychaete worms. Kröncke (1990) postulated that the increase in opportunistic species, on the Dogger Bank between 1951 and 1987 may be due to eutrophication. However, the biotope is considered to be **Not Sensitive** at the pressure benchmark that assumes compliance with good status as defined by the WFD.

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

Dense populations of *Lagis koreni* characteristically occur in organically-rich inshore sediments, e.g. off estuary mouths, suggesting that the species may favour organic enrichment (Pearson & Rosenberg, 1978, cited in Rees & Dare, 1993). However, Gordon (1966, cited in Nicolaidou, 1988) found that sediment reworking was inversely related to the organic carbon concentration of the sediment.

Borja *et al.* (2000) assigned *Lagis koreni* and *Phaxas pellucidus* to their Group I – 'species very sensitive to organic enrichment and present under unpolluted conditions (initial state)', whereas Gittenberger & Van Loon (2011) assigned *Lagis koreni* to Ecological Group III 'species tolerant to excess organic matter enrichment. These species may occur under normal conditions, but their populations are stimulated by organic enrichment (slight unbalance situations)', but gave no information concerning *Phaxas pellucidus.*

Although no further specific information regarding the response of *Phaxas pellucidus* to changes in nutrient levels was found, as filter-feeders, the species is likely to benefit from some organic enrichment.

Sensitivity assessment. No direct evidence of the characterizing species' specific tolerances to organic enrichment was found. It is likely that the characterizing species in the biotope are able to utilize additional organic load as food. However, it is possible that the characterizing species experience decreases in abundance as a result of organic enrichment, which can lead to shifts in community composition towards one dominated by tolerant species, such as polychaete worms (Pearson & Rosenberg, 1978). Additionally, Forrest *et al.* (2009) identified that the recovery of muddy sediments beneath fish farms from enrichment can be highly variable and may be many years at poorly flushed sites, suggesting that the low energy environments that characterize the biotope may allow for prolonged periods of organic load sedimentations enhancing the adverse effects to sensitive characterizing species. Resistance is therefore assessed as **Low** (loss 25-75%), but with low confidence. Resilience is likely to the **Medium** and the overall sensitivity of the biotope judged as **Medium**.

Physical Pressures

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

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

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

If the sediment that characterizes the biotope were replaced with rock substrata, this would represent a fundamental change to the physical character of the biotope. The characterizing species would no longer be supported and the biotope would be lost and/or reclassified.

Sensitivity assessment. Resistance to the pressure is considered **None**, and resilience **Very Low**, given the permanent nature of this pressure. Sensitivity has been assessed as **High**. Although no specific evidence is described, confidence in this assessment is 'High' due to the incontrovertible nature of this pressure.

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

Records indicate that SS.SMu.CSaMu.LkorPpel occurs in sandy muds (Connor *et al.*, 2004), with the characterizing species within the biotope likely to occur within due to their narrow sediment preferences, as *Lagis koreni* typically occurs in sandy muds and muddy sands (Mayhew, 2007), and *Phaxas pellucidus* seems to have preferences for fine mixed sands (Neish, 2008). Furthermore, Lambert (1991, cited in Olivier *et al.*, 1996) demonstrated that *Lagis koreni* (studied as *Pectinaria koreni*) post-larvae efficiently select muddy and muddy-fine sand over clean fine-sand sediment.

Sensitivity assessment. The characterizing species of SS.SMu.CSaMu.LkorPpel are likely to be resistant to a change in one Folk class from, for example, muddy sand to sandy mud (based on the Long, 2006 simplification). However, this would probably represent a fundamental change in the character of the biotope, and a change in the abundance of the characteristic species, resulting in the loss and/or reclassification of the biotope. Resistance is therefore assessed as **None** and resilience as **Very Low**, given the permanent nature of this pressure. The biotope is therefore considered to have **High** sensitivity to a change in seabed type by one Folk class.

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

Sedimentary communities are likely to be highly intolerant of substratum removal, which will lead to partial or complete defaunation, expose underlying sediment, which may be anoxic and/or of a different character, and lead to changes in the topography of the area (Dernie *et al.*, 2003). Any remaining species, given their new position at the sediment / water interface, may be exposed to unsuitable conditions. Newell *et al.* (1998) state that removal of 0.5 m depth of sediment is likely to eliminate benthos from the affected area. Some epifaunal and swimming species may be able to avoid this pressure. Removal of 30 cm of sediment is considered to remove species that occur at the surface and within the upper layers of sediment, such as the characterizing species of this biotope. For example, *Lagis koreni* inhabits the top 10 cm of the sediment (Mayhew, 2007) and were incapable of reconstructing their delicate sand-tubes once removed from them, resulting in mortality (Schäfer, 1972). No evidence was found on depth of burial for *Phaxas pellucidus*. Although razor clams are able to burrow rapidly into sediments making them difficult to capture, their short siphons indicate that their usual position in the sediment is close to the surface. However, even with this mobility, it is assumed that this species is unlikely to escape extraction of substratum to 30 cm. This environmental position, which together with shell fragility, is likely to render the species vulnerable and result in a small proportion of the population would be damaged and killed.

Recovery of the sedimentary habitat would occur via infilling, although some recovery of the biological assemblage may take place before the original topography is restored, if the exposed, underlying sediments are similar to those that were removed. Newell *et al.* (1998) indicate that local hydrodynamics (currents and wave action) and sediment characteristics (mobility and supply) strongly influence the recovery of soft sediment habitats.

Sensitivity assessment. Extraction of 30 cm of sediment will remove the characterizing biological component of the biotope so resistance is assessed as **Low**. SS.SMu.CSaMu.LkorPpel occurs in low energy environments, so resilience is therefore judged as **Medium** (see resilience section). Sensitivity has been assessed as **Medium**.

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

The characterizing species of SS.SMu.CSaMu.LkorPpel are infaunal and hence have some protection against surface abrasion only. However, they require contact with the surface for respiration and feeding, so siphons and delicate polychaete feeding structures may be damaged or withdrawn as a result of surface disturbance, resulting in loss of feeding opportunities and compromised growth.

As a deposit-feeder, *Lagis koreni* is motile while feeding within surface layer of sediments. But adults are incapable of reconstructing (delicate) sand tubes once removed from them. Hence, mortality following any damage from trawl/tickler chain disturbance is likely to be very high (Schäfer, 1972, cited in Rees & Dare, 1993). It is likely the species is more vulnerable after dark, as the species is more active feeding at the sediment surface at darkness (Nicolaidou, 1988).

Reiss *et al.* (2009) found that higher intensities of trawling were related to lower levels of production of the larger infauna, while there was no significant relationship of production with fishing intensity for the smallest size fraction. However, *r*-selected species, such as characterizing polychaete *Lagis koreni*, occurred in highest abundances in the heavily trawled areas. These opportunistic species may indeed benefit from fishing disturbance due to their ability to respond to favourable conditions created by disturbance events by quickly using additional resources such as space and food (Pearson & Rosenberg, 1978; Warwick, 1986).

No evidence was found on depth of burial for *Phaxas pellucidus*. Razor clams are able to burrow rapidly into sediments making them difficult to capture, although their short siphons indicate that their usual position in the sediment is close to the surface. Due to this mobility, it is assumed that this species could escape from surface abrasion. Bivalves such as *Phaxas pellucidus*, together with starfish have been reported to be relatively resistant to trawling (Bergman & Van Santbrink, 2000).

Hiddink *et al.* (2006) reported direct mortality of up to 31% of *Lagis koreni* (studied as *Pectinaria koreni*) caused by a single passage of a 4 m and 12 m trawl on sandy and silty sediments, and for *Phaxas pellucidus* of 27% (12 m beam trawl with ticklers), 29% and 33% (4 m beam trawl fitted with ticklers in silty and sandy sediments respectively), and 32% (otter trawl). The authors also noted that higher mortality occurs in silty areas compared to sandy areas, reflecting a deeper penetration of beam trawls into a softer seabed. Additionally, Ball *et al.* (2000b) found that *Phaxas pellucidus* was present at a wreck site that prevented fishing disturbance but were absent from adjacent *Nephrops* trawling grounds, indicating that this species may be sensitive to fishing impacts. Duineveld *et al.* (2007) also found abundances of *Phaxas pellucidus* and other fragile bivalves were higher in areas where fishing was excluded. Examination of historical and recent samples suggest that the spatial presence of *Phaxas pellucidus* in the North Sea has more than halved in comparison with the number of ICES rectangles in which they were sampled at the beginning of the century, apparently in response to fishing effort (Callaway *et al.*, 2007).

In the event of damage caused to the characterizing species as a result of this pressure, damaged or undamaged animals are likely to experience increased predation pressure, particularly *Lagis koreni*, which is a significant food-source for commercially important demersal fish, especially dab and plaice (Macer; 1967; Lockwood, 1980; Basimi & Grove, 1985). Peer (1970) estimated that about 80% of mortality of the related species *Pectinaria hyperborean* was due to predation in

Canadian waters.

Furthermore, SS.SMu.CSaMu.LkorPpel occurs in sandy muds (Connor *et al.*, 2004). Abrasion events caused by a passing fishing gear, or scour by objects on the seabed surface are likely to have marked impacts on the substratum and cause turbulent resuspension of surface sediments. When used over fine muddy sediments, trawls are often fitted with shoes designed to prevent the boards digging too far into the sediment (M.J. Kaiser, pers. obs., cited in Jennings & Kaiser, 1998). The effects may persist for variable lengths of time depending on tidal strength and currents, and may result in a loss of biological organization and reduce species richness (Hall, 1994; Bergman & Van Santbrink, 2000; Reiss *et al.*, 2009) (see change in suspended solids and smothering pressures). The effects of trawling on infauna are greater in areas with low levels of natural disturbance compared to areas of high natural disturbance (e.g. Hiddink *et al.*, 2006). In a meta-analysis of the impacts of different fishing activities on the benthic biota of different habitats, muddy sands were found to be vulnerable to the impacts of fishing activities, with recovery times predicted to take years (Kaiser *et al.*, 2006). The long recovery time for muddy sands is due to the fact that these habitats are mediated by a combination of physical, chemical and biological processes (compared to sand habitats which are dominated by physical processes and recovery time takes days to months).

Sensitivity assessment. The characterizing species live infaunally and are considered to have some protection against surface disturbance. However, the evidence presented suggests that soft bodied organisms and fragile shells are likely to be damaged and removed by abrasion. Resistance to abrasion is therefore considered **Low**. Resilience of the biotope is likely to be **Medium**. The biotope is therefore considered to have **Medium** sensitivity to abrasion or disturbance of the surface of the seabed.

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

Activities that disturb the surface and penetrate below the surface would remove/damage infaunal species such as the characterizing species within the direct area of impact. The footprint of the impact will depend on the type of gear used (Hall *et al.*, 2008).

Lagis koreni adults are incapable of reconstructing (delicate) sand tubes once removed from them, hence mortality following any damage from trawl/tickler chain disturbance is likely to be very high (Schäfer, 1972, cited in Rees & Dare, 1993). Hiddink *et al.* (2006) reported direct mortality of up to 31% of *Lagis koreni* (studied as *Pectinaria koreni*) caused by a single passage of a 4 m and 12 m trawl on sandy and silty sediments, and for *Phaxas pellucidus* of 27% (12 m beam trawl with ticklers), 29% and 33% (4 m beam trawl fitted with ticklers in silty and sandy sediments respectively), and 32% (otter trawl). The authors also noted that higher mortality occurs in silty areas compared to sandy areas, reflecting a deeper penetration of beam trawls into a softer seabed. Additionally, Ball *et al.* (2000b) found that *Phaxas pellucidus* was present at a wreck site that prevented fishing disturbance but were absent from adjacent *Nephrops* trawling grounds, indicating that this species may be sensitive to fishing impacts. Duineveld *et al.* (2007) also found abundances of *Phaxas pellucidus* and other fragile bivalves were higher in areas where fishing was excluded. Examination of historical and recent samples suggest that the spatial presence of *Phaxas pellucidus* in the North Sea has more than halved in comparison with the number of ICES rectangles in which they were sampled at the beginning of the century, apparently in response to fishing effort (Callaway *et al.*, 2007). Eleftheriou & Robertson (1992) observed large numbers of *Ensis ensis* killed or damaged by dredging operations and Gaspar *et al.* (1998) reported high levels of damage in *Ensis siliqua* from fishing.

Furthermore, penetrative events caused by a passing fishing gear are also likely to have marked impacts on the substratum and cause turbulent re-suspension of surface sediments. When used over fine muddy sediments, trawls are often fitted with shoes designed to prevent the boards digging too far into the sediment (M.J. Kaiser, pers. obs., cited in Jennings & Kaiser, 1998). Trawling can create suspended sediment plumes up to 10 m above the bottom (Churchill, 1989 cited in Clarke & Wilber, 2000). The effects may persist for variable lengths of time depending on tidal strength and currents and may result in a loss of biological organization and reduce species richness (Hall, 1994; Bergman & Van Santbrink, 2000; Reiss *et al.*, 2009) (see change in suspended solids and smothering pressures). A meta-analysis of over 100 experimental fishing impact studies showed that beam trawling, scallop dredging and otter trawling all had significant short-term impacts in muddy sand habitats, with most severe effect on suspension feeders (Kaiser *et al.*, 2006). Jennings *et al.* (2001) found that trawling in the muddy sand region led to significant decreases in infaunal biomass and production in the North Sea, with the abundance of larger individuals depleted more than smaller ones.

Sensitivity assessment. A large proportion of the characterizing species in the biotope is likely to be lost or severely damaged, depending on the scale of the activity (see abrasion pressure). Therefore, a resistance of **Low** is suggested. Muddy sand habitats have been reported as having the longest recovery times, whilst mud habitats had an 'intermediate' recovery time (compared to clean sand communities which had the most rapid recovery rate) (Dernie *et al.*, 2003). Resilience is probably **Medium**, and therefore the biotope's sensitivity to this pressure is likely to be **Medium**.

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

Changes in suspended sediment and siltation rate (resulting from changes in the hydrographic regime, run-off from the land or coastal construction) are likely to result in changes in the sediment composition of the surface layers and hence the communities present. Increased suspended sediment may lead to decreased light penetration, possible clogging of feeding organs of suspension feeders such as *Phaxas pellucidus*, and the possibility of smothering of whole organisms (see smothering pressure). However, community members of this biotope live beneath the sediment surface or are mobile, and are unlikely to be directly exposed to changes in suspended solids. An increase in turbidity, reducing light availability will reduce primary production in the biotope. However, the majority of productivity in SS.SMu.CSaMu.LkorPpel is secondary (detritus) and so is not likely to be significantly affected by changes in turbidity. Nevertheless, primary production by pelagic phytoplankton and microphytobenthos do contribute to benthic communities and long-term increases in turbidity may reduce the overall organic input to the detritus, which are the main source of food for characterizing species *Lagis koreni*. For most benthic deposit feeders, food is suggested to be a limiting factor for populations (Levington, 1979; Hargrave, 1980). Consequently, an increase in suspended particulates and subsequent increased deposition of organic matter in sheltered environments where sediments have high mud content, will increase food resources to deposit feeders.

Buchanan & Moore (1986) found that a decline in quantities of organic matter changed the infauna of a deposit feeding community, which is essentially food limited. This may lead to a shift in community structure with increased abundance of deposit feeders and a lower proportion of suspension feeders (as feeding is inhibited where suspended particulates are high and the sediment is destabilised by the activities of deposit feeders) (Rhoads & Young, 1970).

An increase in suspended solids in the water can considerably reduce the quantity of dissolved oxygen, as well as increase the production of mucus to protect the gills from clogging, which consequently can impair metabolism of filter-feeding bivalves, such as *Phaxas pellucidus* (Moore, 1977). A decrease in siltation may equally affect growth and fecundity if the supply of organic particulate matter declines, given that the particles taken are not discriminated upon nutritional value (Moore, 1977 and references therein). According to Widdows *et al.* (1979) growth of filter-feeding bivalves may be impaired at suspended particulate matter (SPM) concentrations >250 mg/l. The dominance of *Phaxas pellucidus* in areas subject to dredge soil dumping and subsequent further deposition (Rees *et al.*, 1992) suggest that this species would not be sensitive to increased turbidity, to either increased seston or subsequent deposition following re-suspension of sediments.

Sensitivity assessment. Resistance and resilience of the biotope are assessed as **High**, so the biotope is considered **Not Sensitive** to a change in suspended solids at the pressure benchmark level.

Smothering and siltation rate changes (light)	High Q: Medium A: Low C: Low	High Q: High A: High C: High	Not sensitive Q: Medium A: Low C: Low

No direct evidence concerning the tolerance of the biotope or the characterizing species to overburden was found. However, the biotope is characterized by burrowing species such as *Lagis koreni* and *Phaxas pellucidus* that are likely to be able to burrow upwards and therefore unlikely to be adversely affected by smothering of 5 cm sediment. For example, adults of *Lagis koreni* are capable of upwardly migrating if lightly buried by additional sediment (Schäfer, 1972 cited in Rees & Dare, 1993).

Hinchey *et al.* (2006) investigated the responses of estuarine benthic invertebrates to sediment burial and concluded that species-specific response to burial varied as a function of motility, living position, and inferred physiological tolerance of anoxic conditions while buried. Although the characterizing species were not included in the study, increased overburden stress did not significantly decrease survival and growth of the juvenile bivalve, *Limecola balthica*, but significantly caused decline of survival of the studied juvenile polychaete, *Streblospio benedicti*. The depth of sediment deposited varied between 0-24.6 cm and 0-8.4 cm, respectively.

Furthermore, a study of the ecological effects of dumping dredged sediments by Essink (1999) reported that resistance of mobile macrobenthos varied greatly with species. For polychaetes, the author reported tolerances of up to 50 cm of mud for species such as *Nepthys* and *Nereis*, and up to 80 cm of sand. For bivalves in the subtidal, *Ensis* spp. were reported to survive up to 50 cm of both mud and sand, but no further information was available on the rates of survivorship or the time taken to reach the surface.

Furthermore, *Lagis koreni* was reported as dominant at a dredged-material ground in Liverpool Bay, probably because of the species opportunistic life cycle (Whomerslwey *et al.*, 2008). Similarly, Rees *et al.* (1992, from Connor *et al.*, 2004) report that *Phaxas pellucidus* can become dominant in areas where dredge spoil is dumped. However, it is not clear whether this relates to vertical migration and survivability or an increase in habitat suitability enhancing post-dredging colonization (as seems more likely).

Rees *et al*. (1992) reported that the biotopes SS.SSa.CMuSa.AalbNuc and SS.SMu.CSaMu.LkorPpel display cyclical behaviour in the Liverpool Bay area, with the community periodically switching from one biotope to the other, and it was suggested this was possibly in relation to the disposal of dredge spoil (Robinson *et al*., 2001 cited in Rees *et al*., 1992).

The character of the overburden is an important factor determining the degree of vertical migration. Individuals are more likely to escape from a covering similar to the sediments in which species are normally found. The biotope occurs in exposed and moderately exposed wave exposure conditions, and a range of tidal streams from very weak to strong (Connor *et al*., 2004). Dispersion of fine sediments may be rapid, and this could mitigate the magnitude of this pressure by reducing the time exposed, as 'light' deposition of sediments is likely to be cleared in a few tidal cycles in areas of higher water flow.

Sensitivity assessment. The evidence suggests that characterizing species *Lagis koreni* and *Phaxas pellucidus* are likely to be able to burrow through, although sudden smothering would temporarily halt feeding and respiration, compromising growth and reproduction owing to energetic expenditure. Beyond re-establishing burrow openings or moving up through the sediment, there is evidence of synergistic effects on burrowing activity of marine benthos and mortality with changes in time of burial, sediment depth, sediment type and temperature (Maurer *et al*., 1986). However, the biotope is likely to resist smothering at the benchmark level. Resistance is therefore assessed as **High**, and resilience is also **High** (by default), so that the biotope is considered **Not Sensitive** to a 'light' deposition of up to 5 cm of fine material added to the seabed in a single, discrete event.

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

No direct evidence concerning the tolerance of the biotope or the characterizing species to overburden was found. However, the biotope is characterized by burrowing species such as *Lagis koreni* and *Phaxas pellucidus* that are likely to be able to burrow upwards through deposited material. For example, adults of *Lagis koreni* are capable of upwardly migrating if lightly buried by additional sediment (Schäfer, 1972 cited in Rees & Dare, 1993).

Hinchey *et al*. (2006) investigated the responses of estuarine benthic invertebrates to sediment burial and concluded that species-specific response to burial varied as a function of motility, living position, and inferred physiological tolerance of anoxic conditions while buried. Although the characterizing species were not included in the study, increased overburden stress did not significantly decrease survival and growth of the juvenile bivalve, *Limecola balthica*, but significantly caused decline of survival of the studied juvenile polychaete, *Streblospio benedicti*. The depth of sediment deposited varied between 0-24.6 cm and 0-8.4 cm, respectively.

Furthermore, a study of the ecological effects of dumping dredged sediments by Essink (1999) reported that resistance of mobile macrobenthos varied greatly with species. For polychaetes, the author reported tolerances of up to 50 cm of mud for species such as *Nepthys* and *Nereis*, and up to 80 cm of sand. For bivalves in the subtidal, *Ensis* spp. were reported to survive up to 50 cm of both mud and sand, but no further information was available on the rates of survivorship or the time taken to reach the surface.

Furthermore, *Lagis koreni* was reported as dominant at a dredged-material ground in Liverpool Bay, probably because of the species opportunistic life cycle (Whomerslwey *et al*., 2008). Similarly, Rees *et al*. (1992, from Connor *et al*., 2004) report that *Phaxas pellucidus* can become dominant in areas where dredge spoil is dumped. However, it is not clear whether this relates to vertical migration and survivability or an increase in habitat suitability enhancing post-dredging colonization (as seems more likely).

Rees *et al.* (1992) reported that the biotopes SS.SSa.CMuSa.AalbNuc and SS.SMu.CSaMu.LkorPpel display cyclical behaviour in the Liverpool Bay area, with the community periodically switching from one biotope to the other, and it was suggested this was possibly in relation to the disposal of dredge spoil (Robinson *et al*., 2001 cited in Rees *et al*., 1992).

The character of the overburden is an important factor determining the degree of vertical migration. Individuals are more likely to escape from a covering similar to the sediments in which species are normally found. The biotope occurs in exposed and moderately exposed wave exposure conditions, and a range of tidal streams from very weak to strong (Connor *et al*., 2004). Dispersion of fine sediments following a 'heavy' deposition of sediments will likely need a few tidal cycles to clear, enhancing the magnitude of exposure to this pressure.

Sensitivity assessment. The evidence suggests that characterizing species *Lagis koreni* and *Phaxas pellucidus* are likely to be able to burrow through, although sudden smothering would temporarily halt feeding and respiration, compromising growth and reproduction owing to energetic expenditure. Beyond re-establishing burrow openings or moving up through the sediment, there is evidence of synergistic effects on burrowing activity of marine benthos and mortality with changes in time of burial, sediment depth, sediment type and temperature (Maurer *et al*., 1986). Bivalve and polychaete species have been reported to migrate through depositions of sediment greater that the benchmark (30 cm of fine material added to the seabed in a single discrete event) (Bijkerk, 1988; Powilleit *et al*., 2009; Maurer *et al*., 1982). However, it is not clear whether the characterizing species are likely to be able to migrate through a maximum thickness of fine sediment because muds tend to be more cohesive and compacted than sand. Some mortality of the characterizing species is likely to occur. Resistance is therefore assessed as **Low** (25-75% loss) and resilience as **Medium** and the biotope is considered to have **Medium** sensitivity to a 'heavy' deposition of up to 30 cm of fine material in a single discrete event.

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 is available on which to assess this pressure.

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 in the biotope may respond to vibrations from predators or excavation by retracting their palps into their tubes or by burrowing deeper into the sediment. However, the characterizing species are unlikely to be affected by noise pollution and so the biotope is assessed as **Not Sensitive**.

Introduction of light or shading	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not sensitive Q: NR A: NR C: NR

Lagis koreni can sense light and react to it, showing to be governed by an endogenous diurnal rhythm (Nicolaidou, 1988). It is likely the species is more active in darkness to decrease the possibility of being preyed upon, since some of its predators, such as plaice, flounder and dab are all predominantly visual feeders (De Groot, 1971). A change in the incidence of lighting that results in continuous lighting may affect growth and survival of *Lagis koreni*, by limiting feeding opportunities and increasing the risk of predation by visual predators. However, Peer (1970) estimated that about 80% of mortality of the related species *Pectinaria hyperborean* was due to predation in Canadian waters, demonstrating that the species is already able to cope with high levels of predation. It is therefore unlikely that an increase would impact the community. Additionally, SS.SMu.CSaMu.LkorPpel is a circalittoral biotope (Connor *et al*., 2004), not characterized by the presence of primary producers and therefore, not directly dependent on sunlight.

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 to biotopes restricted to open waters.

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 to seabed habitats. NB. Collision by grounding vessels is addressed under surface abrasion.

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

Lagis koreni (studied as *Pectinaria koreni*) can sense light and react to it, showing more activity in darkness to avoid visual predators (Nicolaidou, 1988). However, no evidence was found of the species demonstrating a defence mechanism which could be triggered by visual disturbance. Additionally, both the characterizing species of the biotope live infaunally, so are unlikely to be affected by visual disturbance such as shading.

Biological Pressures

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

The important characterizing species in the biotope are not cultivated or likely to be translocated. This pressure is therefore considered **Not Relevant**.

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

Subtidal muds are considered highly sensitive to non-native invasive species due to the potential for habitat and ecological change when these are established and the difficulty in removing them. However, no evidence can be found on the impacts of INNS on the characterizing species within these biotopes. For this reason the effect of this pressure has been given as **No Evidence**. Literature for this pressure should be revisited.

Introduction of microbial pathogens	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

Zoogonoides viviparous is a helminth parasite known to use *Lagis koreni* as a host (Peoples, 2013). Although polychaetes have been shown to combat parasitism with immune responses, details of the physiological tool of this infection were not provided.

More than 20 viruses have been described for marine bivalves (Sinderman, 1990). Bacterial diseases are more significant in the larval stages and protozoans are the most common cause of epizootic outbreaks that may result in mass mortalities of bivalve populations. Parasitic worms, trematodes, cestodes and nematodes can reduce growth and fecundity within bivalves and may, in some instances, cause death (Dame, 1996). However, no information specifically concerning the effects of microbial pathogens and parasites on the viability of the characterizing species was found.

Sensitivity assessment. No direct evidence of the biotope being affected by the introduction of microbial pathogens was found as with which to assess this pressure.

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 obligate life-history or ecological associations were identified between this ecological group and currently targeted species although removal of predators may be beneficial for *Lagis koreni*, which is a significant food-source for commercially important demersal fish, especially dab and plaice (e.g Macer, 1967; Lockwood, 1980; Basimi & Grove, 1985). However, it is extremely unlikely that any of the species indicative of sensitivity would be targeted for extraction. This pressure is therefore considered **Not Relevant**.

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

Direct, physical impacts are assessed through the abrasion and penetration of the seabed pressures, while this pressure considers the ecological or biological effects of by-catch. Species in these biotopes, including the characterizing species, may be damaged or directly removed by static or mobile gears that are targeting other species (see abrasion and penetration pressures). Loss of these species would alter the character of the biotope resulting in re-classification, and would alter the physical structure of the habitat resulting in the loss of the ecosystem functions such as secondary production performed by these species.

Sensitivity assessment. Removal of the characterizing species would result in the biotope being lost or reclassified. Thus, the biotope is considered to have a resistance of **Low** to this pressure and to have **Medium** resilience, resulting in the sensitivity being judged as **Medium**.

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