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

Nephtys hombergii, *Limecola balthica* and *Streblospio shrubsolii* in littoral sandy mud

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

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

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

Researched by   Matthew Ashley   **Refereed by**   Admin

Summary

☰ UK and Ireland classification

EUNIS 2008	A2.311	*Nephtys hombergii, Macoma balthica* and *Streblospio shrubsolii* in littoral sandy mud
JNCC 2015	LS.LMu.MEst.NhomLimStr	*Nephtys hombergii, Limecola balthica* and *Streblospio shrubsolii* in littoral sandy mud
JNCC 2004	LS.LMu.MEst.NhomMacStr	*Nephtys hombergii, Macoma balthica* and *Streblospio shrubsolii* in littoral sandy mud
1997 Biotope		

🏷 Description

Soft mud with a fine sand fraction, in variable salinity conditions, typically close to the head of estuaries. The infauna is dominated by the polychaete worm *Streblospio shrubsolii*, the polychaete *Nephtys hombergii*, oligochaetes of the genus *Tubificoides*, and the Baltic tellin *Limecola*

balthica. The ragworm *Hediste diversicolor* and the spire shell *Hydrobia ulvae* are often common or abundant (JNCC, 2015).

↓ Depth range

Mid shore, Lower shore

🏛 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

This biotope occurs in mud sedimentswith a fine sand fraction, in variable salinity conditions, typically close to the head of estuaries. The infauna is dominated by the polychaete worm *Streblospio shrubsolii*, the polychaete *Nephtys hombergii*, oligochaetes of the genus*Tubificoides*, and the Baltic tellin *Limecola balthica*. The ragworm *Hediste diversicolor* and the spire shell *Hydrobia ulvae* are often common or abundant (JNCC, 2015).

The characterizing species *Streblospio shrubsolii*, *Nephtys hombergii*, oligochaetes of the genus*Tubificoides* and the bivalve *Limecola balthica* are considered in this sensitivity assessment.

Resilience and recovery rates of habitat

When impacted this biotope may recover through repair of damaged individuals, adult migration by mobile species and recolonization by pelagic larvae. *Streblospio shrubsolii and Tubificoides benedii* are considered opportunistic species and exhibit shorter lifespans and faster growth rates. *Streblospio shrubsolii* displays a flexible life history and is viewed as an indicator species, where presence in abundance indicates stressed environments (Borja *et al.*, 2000).*Tubificoides benedii* is likely to rapidly increase in abundance in disturbed sediments and polluted conditions (Gray *et al.*, 1990; Borja *et al.*, 2000; Gogina *et al.*, 2010).

Recovery of *Nephtys hombergii* has been assessed to be very high as re-population would occur initially relatively rapidly via adult migration and later by larval recruitment. Dittman *et al.* (1999) observed that *Nephtys hombergii* was amongst the macrofauna that colonized experimentally disturbed tidal flats within two weeks of the disturbance that caused defaunation of the sediment. However, if sediment is damaged recovery is likely to be slower, for instance *Nephtys hombergii* abundance was reduced by 50% in areas where tractor towed cockle harvesting was undertaken on experimental plots in Burry inlet, south Wales, and had not recovered after 86 days (Ferns *et al.*, 2000). *Nephtys hombergii* has a 3-10 year lifespan, and reaches maturity at 1-2 years and these traits suggest the species is likely to require longer to recover than more opportunistic (shorter lifespan, earlier age at maturity).

The life history characteristics of *Macoma balthica* give the species strong powers of recoverability. Adults spawn at least once a year and are highly fecund (Caddy, 1967). Females are capable of producing 10,000-30,000 eggs (MES, 2010). There is a planktotrophic larval phase which lasts up to 2 months (Fish & Fish, 1996) and so dispersal over long distances is potentially possible given a suitable hydrographic regime. Following settlement, development is rapid and sexual maturity is attained within 2 years (Gilbert, 1978; Harvey & Vincent, 1989). In addition to larval dispersal, dispersal of juveniles and adults occurs via burrowing (Bonsdorff, 1984; Guenther, 1991), floating (Sörlin, 1988) and probably via bedload transport (Emerson & Grant, 1991). It is expected therefore that recruitment can occur from both local and distant populations. Bonsdorff (1984) studied the recovery of a *Macoma balthica* population in a shallow, brackish bay in SW Finland following the removal of the substratum by dredging in the summer of 1976. Recolonization of the dredged area by *Macoma balthica* began immediately after the disturbance to the sediment and by November 1976, the *Macoma balthica* population had recovered to 51 individuals/m. One year later there was no detectable difference in the *Macoma balthica* population between the recently

dredged area and a reference area elsewhere in the bay. In 1976, two generations could be detected in the newly established population indicating that active immigration of adults was occurring in parallel to larval settlement. In 1977, up to six generations were identified, giving further evidence of active immigration to the dredged area.

In general, recovery of sandy mud biotopes is dependent on the return of suitable sediment and recruitment of individuals. When sandy mud assemblages are disturbed, recruitment comes from a combination of adult migration and larval immigration with larval importance increasing with the size of the spatial footprint. Overall recovery will vary according to site-specific factors including hydrographic regime and sediment supply. Once suitable substratum returns, initial recolonization is likely to be rapid, especially for rapidly reproducing species such as polychaetes, oligochaetes and some amphipods and bivalves. The important characterizing species, *Limecola balthica* and *Nephtys hombergii* have lifespans of 3-10 years, exhibit generation times of 1-2 years and reach maturity at 1-2 years. Hence recovery is probably approximately 2 years (High resilience) but full population recovery, following large scale removal of a population may take >2 years (resilience is Medium).

Resilience assessment. Recovery of the opportunistic species characterizing the biotope is likely to occur within months in the case of *Streblospio shrubsolii* and *Tubificoides benedii*, while *Macoma balthica* and *Nephtys hombergii* populations are likely to recover within two years. It is important to consider that recovery times and so resilience will depend on the presence of suitable habitat, typically higher mud content sediment and the opportunity for larvae to enter a region through larvae transport pathways. Resilience is assessed as 'High' for all levels of impact (resistance is **'High'**, **'Medium'** , **'Low'** or '**None'**), although in some instances recovery will not occur until the habitat has recovered and this will depend on site-specific hydrodynamics, sediment supply and other factors.

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

Found from the northern Atlantic, from such areas as the Barents Sea, the Baltic and the North Sea, to the Mediterranean. *Nephtys hombergii* has been reported from as far south as South Africa, suggesting the species can tolerate temperatures above, even a 5°C increase in UK and Irish coasts. Records are limited but Emery & Stevensen (1957) found that *Nephtys hombergii* could withstand summer temperatures of 30-35°C.

Environmental factors, such as temperature, day-length, and tidal or lunar cycles, have been implicated in the timing of spawning of Nephtyidae, in particular, the spring tide phase of the lunar cycle (Bentley *et al.*, 1984). In the Tyne Estuary spawning of *Nephtys hombergii* occurred in May and September, whilst in Southampton Water the species spawned throughout the year with peaks in July and November (Wilson, 1936; Oyenekan, 1986). In Århus Bay, Denmark, *Nephtys hombergii* spawned in August and September, but a decrease in the number of individuals bearing gametes in May and June suggested that at least part of the population spawned in early summer (Fallesen & Jørgensen, 1991). A 5°C increase in temp for one month period, or 2°C for one year is likely to impact timing of reproduction in these areas, although the combination of environmental factors appearing to influence timing (in particular spring tides) may limit the impact of changes in temperature on timing of spawning events.

Streblospio shrubsolii have been shown to reproduce in a temperature range of 7.5°C – 30°C with highest reproduction levels occurring between 16°C – 21°C (Levin & Creed, 1986, Da Fonseca-Genevois & Cazaux, 1987; Chu & Levin, 1989; Lardicci *et al.*, 1997). The case studies returned by literature reviews were based on Mediterranean case study sites, limiting confidence for UK and Irish seas. The timing of reproduction and growth, although occurring throughout the year increased in late spring and early summer, but were strongly reduced during periods of higher temperatures in summer and disappeared or strongly reduced at lower temperatures in winter and (Lardicci *et al.*, 1997). *Streblospio shrubsolii* show timing of growth and reproduction depends on synergistic effects of temperature and photoperiod, suggesting, temperature and photoperiod cues may differ at locations at different latitudes (Chu & Levin, 1989). Both a 5°C increase in temperature for a one month period, or 2°C for one year are within the temperature range reproduction occurs within (7.5°C – 30°C) and within the temperature range where highest reproduction levels occur (16°C – 21°C). Timing and level of reproduction may be affected, however, with some limit on population abundance likely to be caused by a 5°C increase in temp for one month period but this would be unlikely to significantly impact the biotope.

In Europe, *Limecola balthica* occurs as far south as the Iberian Peninsula and, hence, is expected to tolerate higher temperatures than experienced in Britain and Ireland. Oertzen (1969) recorded that *Limecola balthica* (as *Macoma balthica*) could tolerate temperatures up to 49°C before thermal numbing of gill cilia occurred presumably resulting in death. Ratcliffe *et al. (*1981) reported that *Limecola balthica* from the Humber Estuary, UK, tolerated six hours of exposure to temperatures up to 37.5°C with no mortality. However, Barda *et al.* (2014) found that increased temperature reduced growth rates in populations in the Baltic Sea . Beukema *et al.* (2014) also warn that increasing water temperatures as a result of global warming are likely to shorten the growing season (typically late winter to early spring) if warmer spring and summer water temperatures are experienced. Jansen *et al.* (2007) suggest that temperature increases in the Spanish coast along the Bay of Biscay over the past 40 years have caused loss of *Limecola balthica* populations, due to short-term but frequent exposure to >30° C in the Spanish estuaries, which induced elevated maintenance rates in *Limecola balthica*, and ultimately starvation. Jansen *et al.* (2007) predict the southern limit of the species will progressively shift north if temperatures continue to rise.

Sensitivity assessment. Typical surface water temperatures around the UK coast vary, seasonally from 4-19°C (Huthnance, 2010). It is likely that the species are able to resist a long-term increase in temperature of 2°C and may resist a short-term increase of 5°C. Resistance and resilience are therefore assessed as '**High'** and the biotope is judged as '**Not Sensitive'**.

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

Nephtys hombergii are found as far north as the Barents Sea, and would be expected to be resistant to a 5°C decrease in temp for one month period, or 2°C for one year. Environmental factors, such as temperature, day-length, and tidal or lunar cycles, have been implicated in the timing of spawning of the Nephtyidae, in particular the spring tide phase of the lunar cycle (Bentley *et al.*, 1984). Olive *et al.* (1997) found that relative spawning success in a North sea (Newcastle on Tyne) population of *Nephtys hombergii* was positively correlated with winter sea and air temperatures. This suggests a 5°C decrease in temp for a one month period, occurring in winter, or 2°C for one year are likely to impact spawning success.

Streblospio shrubsolii has been shown to reproduce in a temperature range of 7.5°C – 30°C with highest reproduction levels occurring between 16°C – 21°C (Levin & Creed, 1986, Da Fonseca-Genevois & Cazaux, 1987, Chu & Levin, 1989, Lardicci *et al.*, 1997). Reproductive activity disappeared or strongly reduced at lower temperatures in winter in a Mediterranean case study (Lardicci *et al.*, 1997), this case study suggests reproduction would be delayed in UK and Irish populations that experienced both a 5°C decrease in temp for one month period, or 2°C for one year.

The geographical distribution of *Limecola balthica* suggests that it is very tolerant of low temperature. The species occurs in the Gulfs of Finland and Bothnia where the sea freezes for several months of the year (Green, 1968). It must therefore tolerate much lower temperatures than it experiences in Britain and Ireland. Furthermore, *Limecola balthica* was apparently unaffected by the severe winter of 1962/3 which decimated populations of many other bivalve species (Crisp, 1964), and De Wilde (1975) noted that *Limecola balthica* kept at 0°C maintained a high level of feeding activity. It is unlikely, therefore, that in seas around the UK and Ireland *Limecola balthica* would be intolerant of decreases in temperature at the benchmark level.

Sensitivity assessment Typical surface water temperatures around the UK coast vary, seasonally from 4-19°C (Huthnance, 2010). *Streblospio shrubsolii* and *Nephtys hombergii* are likely to be able to resist a long-term decrease in temperature of 2°C and may resist a short-term decrease of 5°C. Temperature may act as a spawning cue and an acute or chronic decrease may result in some delay in spawning, however this is not considered to impact the adult population and may be compensated by later spawning events. Resistance and resilience are therefore assessed as '**High**' and the biotope judged as '**Not Sensitive**'.

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

This biotope occurs on the mid and lower shore of sheltered estuaries exposed to variable (18-35 ppt) salinity (JNCC, 2015). An increase of one MNCR salinity category, at the pressure benchmark, would be to fully marine 30-40 ‰. Short-term fluctuations in salinity are only likely to affect the surface of the sediment, and not deeper buried organisms, since the interstitial or burrow water is less affected. However, under longer term or permanent increase in salinity, sediment waters would be expected to also adjust.

Nephtys hombergii is considered to be a brackish water species (Barnes, 1994) but where the species occurs in open coastal locations the species would have to tolerate salinities of 25 psu and

above. Within a few months of the closure of a dam across the Krammer-Volkerak estuary in the Netherlands, Wolff (1971) observed that species with pelagic larvae or a free-swimming phase, expanded rapidly with a concomitant increase of salinity to 9-15 psu everywhere. Prior to the closure of the dam the estuary demonstrated characteristics of a typical 'salt-wedge' estuary with a salinity gradient from 0.3 to 15 psu. Hence, *Nephtys hombergii* is likely to survive increases in salinity within estuarine environments. In fully marine locations *Nephtys hombergii* may still be found but, may be competitively inferior to other species of Nephtyidae (e.g. *Nephtys ciliata* and *Nephtys hystricis*) and occur in lower densities. An increase to fully marine (30-40 ‰) would therefore be likely to lead to a reduction in density of *Nephtys hombergii*.

Streblospio shrubsolii occurred in subtidal areas of the Thames estuary as well as intertidal flats, suggesting the species is resistant to higher salinities than the 'variable' levels occurring higher in estuaries (Attrill, 1998). Likewise *Tubificoides benedii* has been recorded in high abundance in offshore areas of the North Sea (Gray *et al.*, 1990). Although evidence was limited on response of these species to rapid increases in salinity it is likely they would be resistant to an increase to the fully marine category (30-40 ‰).
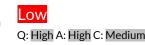
Conde *et al.* (2013) found that Streblospio shrubsolii were a dominant species in low salinity, estuarine conditions (5-9‰) in the Tagus estuary, Portugal. In Ria de Averio, western Portugal *Streblospio shrubsolii* and *Tubificoides benedii* were characterizing species of communities in estuarine sample sites further upstream with lower salinity, suggesting a high resistance to a decrease in salinity (Rodrigues *et al.*, 2011).
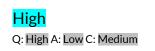
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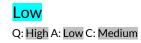
Limecola balthica is found in brackish and fully saline waters but is more common in brackish waters (Clay, 1967b) so may tolerate a state of flux. Seitz (2011) found Limecola balthica (as *Macoma balthica*) distribution across a salinity gradient between a minimum and maximum of 8.8 psu to 19 psu in Cheaspeake Bay was not influenced by salinity. Instead, resource availability was the principal influence on *Limecola balthica* at a broad scale, suggesting changes in one MNCR salinity category would have limited impact. McLusky & Allan (1976) reported that *Limecola balthica* failed to grow at 41 psu. It is likely that *Limecola balthica* would be tolerant of an increase in salinity category to fully marine but further increases to >40‰ are likely to affect growth and condition.

Sensitivity assessment. *Nephtys hombergii* are likely to decrease in abundance following an increase in salinity. Resistance is assessed as **'Low'**, Resilience is assessed as **'High'** (following restoration of salinity regime) and biotope sensitivity is assessed as **'Low'**. Increase in salinity may lead to replacement to the biotope LS.LMu.MEst.HedLim, as the associated HedLim communities occur further down estuaries towards the open coast, in more saline conditions. The infauna in LS.LMu.MEst.HedLim is similar, though the ragworm *Hediste diversicolor* is always abundant, and both *Nephtys hombergii* and *Streblospio shrubsolii* are often absent. The bivalve assemblage tends to be more diverse in LS.LMu.MEst.HedLim (JNCC, 2015).

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

This biotope occurs on the mid and lower shore of sheltered estuaries exposed to variable (18-35 ppt) salinity (JNCC, 2015). Maximum salinity would be expected to be approximately 18-35‰. A decrease of one MNCR salinity category at the pressure benchmark would be to the 'Low' salinity category (<18‰).

Environmental fluctuations in salinity are only likely to affect the surface of the sediment, and not deeper buried organisms, since the interstitial or burrow water is less affected. However, under longer term or permanent increase in salinity, sediment waters would be expected to also adjust.

Nephtys hombergii is considered to be a brackish water species, and has been reported to occur in estuarine locations where salinity is less than 18 psu (Barnes, 1994). Clark & Haderlie (1960) found *Nephtys hombergii* in the Bristol Channel at salinities between 15.9 psu and 25.1 psu. If the salinity were to become intolerable to the polychaete it is likely that as a mobile species, able to both swim and burrow, *Nephtys hombergii* would avoid the change in salinity by moving away so that populations would decline.

Conde *et al.* (2013) found that *Streblospio shrubsolii* were a dominant species in low salinity, estuarine conditions (5-9‰) in the Tagus estuary, Portugal. In Ria de Averio, western Portugal *Streblospio shrubsolii and Tubificoides benedii* were characterizing species of communities in estuarine sample sites further upstream with lower salinity, suggesting a high resistance to a decrease in salinity (Rodrigues *et al.*, 2011).

McLusky & Allan (1976) conducted salinity survival experiments with *Limecola balthica* (as *Macoma balthica*) over a period of 150 days. Survival times declined with decreased salinity. At 12 psu specimens survived 78 days, whilst specimens at 8.5 psu survived 40 days. Some specimens of *Limecola balthica* survived 2.5 days at 0.8 psu, which was apparently due to the animals ability to clamp its valves shut in adverse conditions. McLusky & Allan (1976) also reported that *Limecola balthica* failed to grow (increase shell length) at 15 psu. *Limecola balthica* is found in brackish and fully saline waters (Clay, 1967b) so may tolerate a state of flux. Its distribution in combination with the experimental evidence of McLusky & Allan (1976) suggests that *Limecola balthica* is likely to be very tolerant to a decreased salinity over a short period. A decline in salinity in the long-term may have implications for the species viability in terms of growth, and the distribution of the species may alter as specimens at the extremes retreat to more favourable conditions. Metabolic function should, however, return quickly to normal when salinity returns to original levels. Decreased salinity may also affect the ability of *Limecola balthica* to tolerate contaminants such as heavy metals (see Bryant *et al.*, 1985 & 1985a). Usually, contaminants become more toxic at low salinity (Langston, W.J. pers comm.).

Sensitivity assessment. The characterizing species within the biotope occupy between 'variable' and 'fully marine' category salinities and can tolerate greater osmotic stress for short periods, caused by decreases in salinity below 18‰. Resistance to this decrease in salinity from variable (18-35‰) to low (<18 ppt) is considered likely to lead to some species replacement by polychaetes or oligochaetes more tolerant of low salinity. *Nephtys hombergii* and oligochaetes are likely to remain but *Limecola balthica* is likely to reduce in low salinity conditions. A similar biotope could remain where salinities were close to 18 ppt but a severe reduction in salinity would probably lead to loss of the biotope. Resistance is therefore assessed as **'Low'.** Resilience (following restoration of typical conditions) is **'High'** and sensitivity is assessed as **'Low'**. It should be noted that resistance would be lower, and sensitivity greater, where salinity was reduced to a level close to freshwater. A reduction in salinity could lead to a change in biotope to LS.LMu.UEst.Hed.Ol, which tends to occur in more reduced salinities, further towards the head of

estuaries. The polychaete assemblage is poorer, and molluscs are virtually absent. It is the presence of *Limecola balthica* and *Hydrobia ulvae* that primarily distinguishes NhomLimStr from Hed.Ol (Connor *et al.* 2014).

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

The biotope occurs most often in weak or moderately strong tidal streams (JNCC, 2015) suggesting the species characterizing the biotope can adapt to a range of tidal currents, aided by each species burrowing traits. Sheltered, moderately exposed, exposed.

The hydrographic regime is an important structuring factor in sedimentary habitats. An increase in water flow rate is not likely to affect *Nephtys hombergii, Streblospio shrubsolii* and other characterizing species as they live infaunally. The most damaging effect of increased flow rate (above the pressure benchmark) could be the erosion of the substratum as this could eventually lead to loss of the habitat. Orvain *et al.* (2007) investigated the spatio-temporal variations in intertidal mudflat erodibility in Western France and suggested a potential link between *Polychaeta* and bed erodibility given the high polychaete abundances observed in the study.

Increased water flow rates is likely to change the sediment characteristics in which the species live, primarily by re-suspending and preventing deposition of finer particles (Hiscock, 1983). The characterizing species prefer habitats with silty/muddy substrata which would not occur in very strong tidal streams. Coarser sediments are likely to remain in areas of strongest flow velocity (where finer particles have been re-suspended) (Coates *et al.*, 2014). Species such as *Tubificoides benedii* and other opportunist polychaetes that tolerate coarser particle size will possibly increase in abundance.

Additionally, the consequent lack of deposition of particulate matter at the sediment surface would reduce food availability. 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.

Limecola balthica is likely to experience greater impact from increased water flow as the species thrives in low energy environments, such as estuaries that characterize the biotope (Tebble, 1976). *Limecola balthica* also shows preference for substratum that has a high proportion of fine sediment (Budd & Rayment, 2001). Increased water flow rate is likely to change the sediment characteristics in this biotope, primarily by re-suspending and preventing deposition of finer particles (Hiscock, 1983). This would result in erosion of the preferred habitat, which may cause mortality of some portion of the population of *Limecola balthica*. Higher current velocity (0.18 m/s) recorded in flume experiments conducted in the Isle of Sylt (North Sea) led to juvenile *Limecola balthica* being washed out of the sediment (Zuhlke & Reise, 1994). Green (1968) recorded that towards the mouth of an estuary where sediments became coarser and cleaner, *Limecola balthica* was replaced by another tellin species, *Tellina tenuis*.

Sensitivity assessment. A decrease in water flow may result in accretion of fine sand, and, thereby, a change to muddy sand and mud. As the biotope occurs in association with muddy sand or fine sand a decrease in water flow is unlikely to impact the biotope (although under an excessive deposition of mud or silt, mud communities, e.g. HedLim, or UEst.Tben may replace the biotope, but this is unlikely at the benchmark levels). Finer sediment has a predicted threshold velocity

(flow velocity at which fine grain size sediment would be picked up from the sea bed) of ~0.05 m/s (Gray & Elliott, 2009), therefore an increase of 0.1-0.2 m/s may cause a significant change in grain size of sediments. Resistance is assessed as '**Low**' and resilience is assessed as **'High'**. The resulting sensitivity score is '**Low**' given the potential scenario that an increase in peak mean spring bed flow velocity of between 0.1m/s to 0.2m/s for more than 1 year may result in a characterizing species, *Limecola balthica* being replaced by another species. As well as HedLim, the biotope LS.LMu.UEst.Tben is likely to occur in a combination of lower saliity and mud with a smaller sand fraction, at the head of estuaries. The infauna of LS.LMu.UEst.Tben is a lot poorer, consisting almost exclusively of oligochaetes and, in some cases, *Capitella capitata*.

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

The biotope and characterizing species occur in the mid to low intertidal. All characterizing species would probably survive an increase in emergence. However, the species can only feed when immersed and therefore likely to experience reduced feeding opportunities. Over the course of a year the resultant energetic cost is likely to cause some mortality. In addition, increased emergence is likely to increase the vulnerability to predation from shore birds. A decrease in emergence is likely to allow the biotope to extend its upper limit, where suitable substrata exist.

Opportunistic, deposit feeding polychaetes, such as, *Streblospio shrubsolii* and *Tubificoides benedii* are likely to tolerate stressful conditions, and often out-compete more sensitive species in inter-tidal environments due to greater tolerances Gogina *et al.* (2010). *Nephtys hombergii* is sufficiently mobile to rapidly burrow and seek damper substrates during periods when emergence increases. For instance, Vader (1964) observed that the worm relocates throughout the tidal cycle.

For instance, *Tubificoides benedii* is capable of penetrating the substrate to depths of 10cm, show resistance to hypoxia and are often typified as an 'opportunist' that is adapted to the rapid environmental fluctuations and harsh conditions in estuaries (Gogina *et al.*, 2010). Highest abundances were predicted by Gogina *et al.* (2010) to be related to depth with an optimum of 10 m to 20 m. Further case studies were not returned by literature searches on *Tubificoides benedii*. The studies returned by searches suggest abundance may be limited by a decrease in high water level or a change in time (increase) where substrate is not covered by the sea. An increase in the time the biotope is covered by the sea is likely to result in increased abundance of *Tubificoides benedii*.

Limecola balthica occurs in the upper regions of the intertidal (Tebble, 1976) and is therefore likely to be tolerant of prolonged emergence. It is a bivalve and can close tightly by contraction of the adductor muscle, storing moisture inside the shell. The silty sediments in which the species lives have a high water content and are therefore resistant to desiccation. Furthermore, *Limecola balthica* is mobile and able to relocate in the intertidal by burrowing (Bonsdorff, 1984) or floating (Sörlin, 1988). It would be expected to react to an increase in emergence by migrating down the shore to its preferred position. There may be an energetic cost to this migration but it is not expected that mortality would result. *Limecola balthica* should quickly recover from the energetic cost of relocation.

A case study, predicting changes in biomass of *Limecola balthica* (as *Macoma balthica*) in the Humber estuary, UK (western North Sea) under expected sea level rise conditions displayed negative impacts. As the coastal squeeze resulting from sea level rise would produce steeper and more homogenous beach face profiles, biomass of *Limecola balthica* was predicted to decrease (Fujii & Raffaelli, 2008). The sensitivity assessment given in relation to the benchmark pressure should,

therefore, be interpreted in relation to intertidal habitat availability following the relative sea level changes.

Sensitivity Assessment. Some changes in biotope extent may occur as a result of emergence regime changes. Resistance is therefore assessed as '**Medium**' resilience, following restoration of the tidal regime, is likely to be '**High**', so the biotope is considered to have '**Low**' sensitivity to changes at the pressure benchmark level.

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

As this biotope occurs in sheltered estuaries a change in nearshore significant wave height >3% but <5% is unlikely to lead to wave heights that will cause greater erosion. The following impacts are only likely to occur in the most exposed examples of the biotope, greatest impacts would occur within very exposed area, where increased wave exposure is likely to cause erosion of the substrata and consequently, loss of habitat.

Nephtys hombergii lives infaunally but may sometimes partially emerge to seek and capture food but does not present a significant surface area to wave action to sustain physical damage. Clark & Haderlie (1960) and Clark *et al.* (1962) suggested that strong wave action limited the distribution of *Nephtys hombergii*. Increased wave action for long durations (e.g. 1 year) may ultimately change the nature of the substratum that the polychaete inhabits and its distribution may consequently alter.

Limited zoobenthic biomass has been recorded in areas exposed to strong currents and wave action (Beukema, 2002), limiting food availability to species such as *Nephtys hombergii*, however impacts from this pressure at the benchmark levels may be low for this biotope, as the biotope is limited to sheltered locations. Increases in wave action may therefore remain within the limits of the species tolerance but factors such as sediment redistribution may alter the physical biotope.

Sensitivity assessment. Resistance to a change in nearshore significant wave height >3% but <5% of the main characterizing species *Nephtys hombergii*, *Streblospio shrubsolii* and *Tubificoides benedii* is '**High**', given that the biotope occurs in very sheltered locations and an increase in nearshore significant wave height of >3% but <5% would continue to result in sheltered conditions which are within the species tolerance limits. At the highest benchmark pressure (5% increase) the species exhibit '**High**' resistance through their traits to live in the sediment. Resilience (recoverability) is also '**High**' giving a Sensitivity of '**Not Sensitive**'. Due to limited evidence, confidence in this assessment is Low and the potential for long-term changes to the substratum following continued increase in wave action should be considered.

⚗ Chemical Pressures

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

The biotope is likely to be '**Not sensitive**' at the pressure benchmark that assumes compliance with all relevant environmental protection standards. Although contamination at levels greater than

the pressure benchmark may adversely affect the biotope.

The characterizing species display some resistance to heavy metal concentration. *Aphelochaeta marioni* is tolerant of heavy metal contamination occurring in the heavily polluted Restronguet Creek , Falmouth, UK (Bryan & Gibbs, 1983) and it is also an accumulator of arsenic (Gibbs *et al.*, 1983). *Nephtys hombergii* is also recorded in Restronguet Creek.

The levels of Cu, Zn, As and Sn in the sediments of Restronguet Creek are highly contaminated, in the order of 1500-3500 μg/g (Bryan & Gibbs, 1983). Concentrations of dissolved Zn typically range from 100-2000 μ g/l, Cu from 10-100 μg/l and Cd from 0.25-5.0 μg/l (Bryan & Gibbs, 1983). Analyses of organisms from Restronguet Creek revealed that some species contained abnormally high concentrations of heavy metals. *Nephtys hombergii* from the middle and lower reaches of the creek contained appreciably higher concentrations of Cu (2227 μg/g dry wt), Fe and Zn than comparable specimens of *Hediste diversicolor* (as *Nereis diversicolor*). However, amongst polychaetes within the creek, there was evidence that some metals were regulated. In *Nephtys hombergii* the head end of the worm became blackened and x-ray microanalysis by Bryan & Gibbs (1983) indicated that this was caused by the deposition of copper sulphide in the body wall. In the same study, Bryan & Gibbs (1983) presented evidence that *Nephtys hombergii* from Restronguet Creek possessed increased tolerance to copper contamination. Specimens from the Tamar Estuary had a 96 h LC50 of 250 μg/l, whilst those from Restronguet Creek had a 96 h LC50 of 700 μg/l (35 psu; 13°C). Bryan & Gibbs (1983) suggested that since the area had been heavily contaminated with metals for > 200 years, there had been adequate time for metal-resistant populations to develop especially for relatively mobile species.

Hydrocarbon & PAH contamination	Not Assessed (NA)	Not assessed (NA)	Not assessed (NA)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

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

Contamination at levels greater than the pressure benchmark may adversely influence the biotope. Suchanek (1993) reviewed the effects of oil spills on marine invertebrates and concluded that, in general, on soft sediment habitats, infaunal polychaetes, bivalves and amphipods were particularly affected.

The 1969 West Falmouth Spill of Grade 2 diesel fuel, documented by Sanders (1978), illustrates the effects of hydrocarbons in a sheltered habitat with a soft mud/sand substrata (Suchanek, 1993). The entire benthic fauna was eradicated immediately following the spill and remobilization of oil that continued for a period >1 year after the spill contributed to much greater impact upon the habitat than that caused by the initial spill. Effects are likely to be prolonged as hydrocarbons incorporated within the sediment by bioturbation will remain for a long time owing to slow degradation under anoxic conditions. Oil covering the surface and within the sediment would prevent oxygen transport to the infauna and promote anoxia as the infauna utilise oxygen during respiration. Although *Nephtys hombergii* is relatively tolerant of hypoxia and periods of anoxia, a prolonged absence of oxygen would probably result in the death of it and other infauna.

McLusky (1982) found that petrochemical effluents, including organic solvents and ammonium salts, released from a point source to an estuarine intertidal mudflat of the Forth Estuary, Scotland, caused severe pollution in the immediate vicinity. Beyond 500 m distance the effluent contributed to an enrichment of the fauna in terms of abundance and biomass similar to that reported by Pearson & Rosenberg (1978) for organic pollution; *Nephtys hombergii* was found in the area with

maximum abundance of species and highest total biomass at 500 m from the discharge. It seems likely that significant hydrocarbon contamination would kill affected populations of the species. On return to prior conditions, recolonization is likely via adult migration and larval settlement.

Synthetic compound contamination	Not Assessed (NA)	Not assessed (NA)	Not assessed (NA)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available. Although contamination at levels greater than the pressure benchmark may adversely affect the biotope.

No evidence concerning the specific effects of chemical contaminants on *Nephtys hombergii* was found. Boon *et al*. (1985) reported that *Nephtys species* in the North Sea accumulated organochlorines but, based on total sediment analyses, organochlorine concentrations in Nephtys species were not correlated with the concentrations in the (type of) sediment which they inhabited. Specific effects of synthetic chemicals have been reported for other species of polychaete. Exposure of *Hediste diversicolor* and *Arenicola marina* to Ivermecten resulted in significant mortality (Collier & Pinn, 1998).

At concentrations of 1-3 μg/l of TBT there was no significant effects on the abundance of *Hediste diversicolor* after 9 weeks in a microcosm. However, no juvenile polychaetes were retrieved from the substratum suggesting that TBT had an effect on the larval and/or juvenile stages of these polychaetes, effects may therefore also be present on juveniles of characterizing species of this biotope.

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

Insufficient information was available in relation to characterizing species to assess this pressure. Limited evidence is available on species with similar traits. Beasley & Fowler (1976) and Germain *et al*. (1984) examined the accumulation and transfers of radionuclides in *Hediste diversicolor* from sediments contaminated with americium and plutonium derived from nuclear weapons testing and the release of liquid effluent from a nuclear processing plant. Both concluded that the uptake of radionuclides by *Hediste diversicolor* was small. Beasley & Fowler (1976) found *that Hediste diversicolor* accumulated only 0.05% of the concentration of radionuclides found in the sediment. Both also considered that the predominant contamination pathway for *Hediste diversicolor* was from the interstitial water.

Sensitivity assessment: There is insufficient information available on the biological effects of radionuclides to comment further upon the intolerance of characterizing species to radionuclide contamination. Assessment is given as **'No Evidence'**

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

This pressure is **Not assessed.**

Some, all be it limited evidence was returned by searches on activated carbon (AC). AC is utilised in some instances to effectively remove organic substances from aquatic and sediment matrices.

Lillicrap *et al.* (2015) demonstrate that AC may have physical effects on benthic dwelling organisms at environmentally relevant concentrations at remediated sites.

De-oxygenation	High	High	Not sensitive
	Q: High A: High C: High	Q: High A: Medium C: Medium	Q: High A: Medium C: Medium

Nephtys hombergii inhabits intertidal areas where resistance to low oxygen is needed and sulphide levels can reach up to 1mM (Giere, 1992; Thierman, 1996). As with other characterizing polychaete species *Nephtys hombergii* exhibits the ability to switch from aerobic to anerobic respiration, which provides some protection from the toxic effects of sulphide.

Nephtys hombergii has adapted to such conditions by utilising several strategies. Arndt & Schiedek (1997) found *Nephtys hombergii* to have a remarkably high content of phosphagen (phosphoglycocyamine), which is the primary energy source during periods of environmental stress. With increasing hypoxia, energy is also provided via anaerobic glycolysis, with strombine as the main end-product. Energy production via the succinate pathway becomes important only under severe hypoxia, suggesting a biphasic response to low oxygen conditions which probably is related to the polychaete's mode of life. The presence of sulphide resulted in a higher anaerobic energy flux and a more pronounced energy production via glycolysis than in anoxia alone. Nevertheless, after sulphide exposure under anaerobic conditions of <24 h, Arndt & Schiedek (1997) observed *Nephtys hombergii* to recover completely. Although *Nephtys hombergii* appears to be well adapted to a habitat with short-term fluctuations in oxygen and appearance of hydrogen sulphide, its high energy demand as a predator renders it likely to limit its survival in an environment with longer lasting anoxia and concomitant sulphide exposure. For instance, Fallesen & Jørgensen (1991) recorded *Nephtys hombergii* in localities in Århus Bay, Denmark, where oxygen concentrations were permanently or regularly low, but in the late summer of 1982 a severe oxygen deficiency killed populations of *Nephtys* species (*Nephtys hombergii* and *Nephtys ciliata*) in the lower part of the bay. However, *Nephtys hombergii* recolonized the affected area by the end of autumn the same year. Alheit (1978) reported a LC50 at 8°C of 23 days for *Nephtys hombergii* maintained under anaerobic conditions.

Nephtys hombergii have tolerated extreme hypoxia, leaving the sediment only after 11 days (Nilsson & Rosenberg, 1994). *Nephtys hombergii* in artificially created anoxic conditions were shown to survive for at least 5d (Schöttler, 1982) and do not switch from aerobic to anerobic metabolic pathways until oxygen saturation decreases <12% (Schöttler, 1982).

Macoma balthica appears to be relatively tolerant of deoxygenation. Brafield & Newell (1961) frequently observed that in conditions of oxygen deficiency (e.g. less than 1 mg O2/l). *Macoma balthica* moved upwards to fully expose itself on the surface of the sand. Specimens lay on their side with the foot and siphons retracted but with valves gaping slightly allowing the mantle edge to be brought into full contact with the more oxygenated surface water lying between sand ripples. In addition, *Macoma balthica* was observed under laboratory conditions to extend its siphons upwards out of the sand into the overlying water when water was slowly deoxygenated with a stream of nitrogen. The lower the oxygen concentration became the further the siphons extended. Dries & Theede (1974) reported the following LT50 (medial lethal time) values for *Macoma balthica* maintained in anoxic conditions: 50 - 70 days at 5°C, 30 days at 10°C, 25 days at 15°C and 11 days at 20°C. Theede (1984) reported that the ability of *Macoma balthica* to resist extreme oxygen deficiency was mainly due to cellular mechanisms. Of considerable importance are sufficient accumulations of reserve compounds e.g. glycogen and the ability to reduce energy requirements for maintenance of life by reducing overall activity (Theede, 1984). *Macoma*

balthica is therefore very tolerant of hypoxia, although it may react by reducing metabolic activity. Intolerance is therefore assessed as low. Metabolic function should quickly return to normal when normoxic levels are resumed and so recoverability is recorded as very high. *Macoma balthica* have been shown experimentally to be able to resist time periods of 9 weeks under algal cover (arising from organic enrichment), their long siphon allowing them to reach oxygenated water (Thiel *et al.,* 1998).

Streblospio shrubsolii characteristic species communities in polluted environments (Cooksey & Hyland, 2007) and in Ria de Averio, western Portugal *Streblospio shrubsolii and Tubificoides benedii* were characterizing species of communities in estuarine sample sites further upstream where exposure to dissolved oxygen concentration was likely to be lowest (Rodrigues *et al.,* 2011).

Sensitivity assessment. The characterizing species are adapted to intertidal areas where resistance to low dissolved oxygen concentration is required and therefore resistance is assessed as '**High**' and resilience as '**High**' and the biotope is assessed as '**Not sensitive'** at the pressure benchmark level.

Nutrient enrichment   High   High   Not sensitive

Q: High A: Medium C: High   Q: High A: High C: High   Q: High A: Medium C: High

The biotope is likely to be N**ot sensitive** to the pressure at the benchmark level, however evidence was available on responses to reductions in water quality.

Nephtys hombergii showed resistance to increased pollution in studies along the Spanish Catalan coast. Changes in species composition parallel to the shoreline showed greatest abundance of *Nephtys hombergii* occurred at sample sites closer to water sewage discharges and river outflow (in comparison to non-polluted sites) (Cardell *et al.,* 1999). For the entire species communities, these sites contained greater biomass but reduced species diversity suggesting *Nephtys hombergii* was amongst a small number of species that could exploit these conditions. *Nephtys hombergii* lives infaunally between a depth of 5 and 15 cm where light is not transmitted. An increase in turbidity, associated with is unlikely to have a detectable effect on the viability of the species.

Streblospio shrubsolii occurred amongst other pollution tolerant species including the polychaetes *Capitella capitata*, *Polydora ciliata*, and *Manayunkia aestuarina* and the oligochaetes *Peloscolex benendeni* and *Tubifex pseudogaste* in the Tees estuary during periods of gross pollution in 1971-1973 (Gray, 1976).

Sensitivity assessment. The characterizing species show **High** resistance to increased nutrient enrichment, resilience is therefore also **High,** and the biotope is assessed as **'Not sensitive'.**

Organic enrichment   High   High   Not sensitive

Q: High A: Medium C: Medium   Q: High A: Medium C: Medium   Q: High A: Medium C: Medium

The infaunal habit of *Nephtys hombergii* and its ability to burrow relatively rapidly through, and into the substratum are likely to aid the species in its avoidance of unsuitable conditions. *Nephtys spp.* were present in organically enriched sediments along the Catalan Spanish coast (Cardell *et al.,* 1999) suggesting the species is likely to be resistant to some organic enrichment.

In Ria de Averio, western Portugal *Streblospio shrubsolii and Tubificoides benedii* were characterizing

species of communities further upstream in estuarine sample sites, at sites with increased organic matter (Rodrigues *et al.*, 2011). *Streblospio shrubsolii* are also considered characteristic species communities in polluted environments, suggesting the species is likely to be resistant to increased organic enrichment (Cooksey & Hyland, 2007).

Sensitivity assessment. The characterizing species show **High** resistance to increased organic enrichment, resilience is therefore also **High,** and the biotope is assessed as **'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 assessment. 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

This biotope is only found in sediment, in particular, sandy mud and the burrowing organisms, *Nephtys hombergii*, *Limecola balthica*, *Streblospio shrubsolii* and *Tubificoides benedii* 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. Biotope resistance is assessed as **'None'** as a change at the pressure benchmark would result in loss of the biotope. Resilience is assessed as **'Very low'** as a change at the pressure benchmark is permanent. Sensitivity within the direct spatial footprint of this pressure is, therefore, assessed as '**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 sediment type)	Low Q: High A: Medium C: Medium	Very Low Q: High A: High C: High	High Q: Low A: Low C: Low

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 this biotope three adjacent categories are relevant, these include a change from sandy mud to i) muddy sand, mud or ii) gravelly mud or a change from sand to iii) gravelly sand.

High densities of *Nephtys hombergii* were found in substrata of 0.3% particles >0.25mm and 5.8% <0.125mm in diameter but the worm tolerated up to 3.8% 0.25mm and 2.2-15.9% <0.125mm (Clark *et al.*,1962). *Nephtys hombergii* may be found in higher densities in muddy environments and this tends to isolate it from *Nephtys cirrosa*, which is characteristic of cleaner, fairly coarse sand. An increase in gravel content, although tolerated by *Nephtys hombergii* may lead to increased

abundance of *Nephtys cirrosa* and decreased abundance of *Nephtys hombergii*. Degraer *et al.* (2006) summarise that the higher the medium grain size of the sediment the lower the relative occurrence of *Nephtys hombergii* and in gain sizes over 0.5mm the species was absent in the Belgium part of the North Sea.

Limecola balthica is likely to tolerate increased gravel content as sediment was not shown to affect burrowing (Tallqvist, 2001), however, growth, shell size and body mass were greatest in higher sand content sediment and lower in higher gravel content sediments (Azouzi *et al.*, 2002), suggesting long-term health and abundance may be affected by a permanent increase in gravel content.

Silva *et al.* (2006) found *Streblospio shrubsolii* in an estuarine site in western Portugal, were more closely associated with increasing mud content and decreasing gravel content.

An increase in mud content may also lead to a change to the biotope LS.LMu.UEst.Tben which ccurs in lower salinities, in mud with a smaller sand fraction, at the head of estuaries. The infauna is a lot poorer, consisting almost exclusively of oligochaetes and, in some cases,*Capitella capitata* (Conner *et al.* 2004).

Sensitivity assessment. Characterizing species are resistant to increases in mud content although changes in lower salinitiy regions may lead to changes to the biotope LS.LMu.UEst.Tben. Increase in gravel content may have a greater imapct on the biotope and lead to replacement of *Nephtys hombergii* by *Nephtys cirrosa*, which is characteristic of cleaner, fairly coarse sand. Resistance is assessed as '**Low'**, Resilience is **'Very low'** and Sensitivity as a change at the pressure benchmark is permanenet and sensitivity is assessed as **'High.**

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

The substratum of this biotope consists of soft wet mud with a fine sand fraction (Conner *et al.*, 2004). The characterizing species burrow into the sediment, or tunnel to depths not exceeding 30cm. The process of extraction is considered to remove all biological components of the biotope group. If extraction occurred across the entire biotope, loss of the biotope would occur. Recovery would require substratum to return to soft wet mud with a fine sand fraction.

The characterizing species *Nephtys hombergii* and *Limecola balthica* burrow into the sediment, to depths not exceeding 30cm. The process of extraction is considered to remove all biological components of the biotope group. If extraction occurred across the entire biotope, loss of the biotope would occur. Recovery would require substratum to return to fine sand and muddy sand sediments with scattered pebbles, boulders and cobbles. Recovery of benthic infauna communities from an impact such as extraction of substratum (from activities such as use of bottom towed fishing gears, aggregate dredging or storm impacts) is predicted to follow succession from initial colonization community of opportunistic species that reproduce rapidly, have small body sizes, short lifespans and early reproductive ages, through to a transitional community and finally an equilibrium community of slower growing, longer lived, larger species (Newell *et al.*, 1998).

Hiddink (2003) showed that the density of *Limecola balthica* was reduced in areas in the Wadden sea (Netherlands) that had experienced suction dredging for cockles, which removes the surface sediment, The disturbance to the sediment also appeared to leave the habitat less suitable for

settlement of young *Limecola balthica* (Hiddink, 2003).

Smaller scale extraction of patches of substratum through activities such as bait digging may have impacts over finer spatial scales within the biotope. If the impact is not spread over a larger area the effects are likely to occur within the dug area.

Sensitivity assessment. Resistance to the pressure is considered '**None**', and resilience '**High**' based on the presence of suitable substratum. Biotope sensitivity has been assessed as 'Medium'. (It should be noted that recovery could be longer and sensitivity greater, where remaining sediments are unsuitable).

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

Damage to seabed surface features may occur due to human activities such as bottom towed fishing gear (trawling and dredging) and natural disturbance from storms. Abrasion from boat moorings were demonstrated to also impact species communities close to the mooring buoy in a case study in the Fal and Helford estuaries (south west UK). Coarser sediment was exposed close to mooring buoys, caused by suspension of fine sediments by movement of the chain (Latham *et al.*, 2012). However, fine sand and muddy sediments displayed the least influence from disturbance from moorings, suggesting a smaller impact to this biotope than other intertidal biotopes.

Sensitivity assessment. The characterizing species are burrowing infauna and likely to be relatively protected from a single event of abrasion at the surface, biotope resistance is therefore assessed as **'Medium'** and resilience as **'High'** so that biotope sensitivity is **'Low'.**

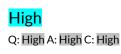| **Penetration or disturbance of the substratum subsurface**	Low	High	Low
	Q: High A: High C: NR	Q: High A: Medium C: High	Q: High A: Medium C: Low

 As the characterizing species are burrowing species the impact from damage to the sub-surface sea bed would be greater than damage to the sea bed surface.

Collie *et al.* (2000) found that abundance of *Nephtys hombergii* declined as a result of fishing activities and mean response of infauna and epifauna communities to fishing activities was much more negative in mud and sand communities than other habitats. *Nephtys hombergii* abundance also significantly decreased in areas of the Solent, UK, where bait digging (primarily for *Nereis virens*) had occurred (Watson *et al.* 2007). Similarly, *Nephtys hombergii* abundance was reduced by 50% in areas where tractor towed cockle harvesting was undertaken on experimental plots in Burry inlet, south Wales, and had not recovered after 86 days (Ferns *et al.*, 2000).

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

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

This biotope is probably exposed to the high levels of suspended sediment characteristic of estuarine conditions. Therefore, the resident species are probably adapted to high suspended sediment levels.

Changes in light penetration or attenuation associated with this pressure are not relevant to *Nephtys hombergii* and *Limecola balthica* biotopes. As the species live in the sediment they are also likely to be adapted to increased suspended sediment (and turbidity). 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 characterizing species.

Increases in turbidity may reduce benthic diatom productivity and productivity of phytoplankton in the water column. Increased clarity, however, may increase primary production. In cases of increased turbidity, impacts may be small for *Nephtys hombergii* as the species feeds on a range of prey in the sediment and reductions in phytoplankton may be mitigated but may limit prey resources, where these are suspension feeders relying on organic solids or phytoplankton.

An increase in suspended solids (inorganic or organic) may also increase food availability of deposit feeders if sediment containing meiofauna, bacteria or organic particles is transported in the water column. However, higher energetic expenditure to unclog the feeding apparatus may occur, which may alter habitat suitability.

An increase in food availability through either increased phytoplankton abundance (under increased water clarity) or increased food resources suspended in the water column (under increased turbidity) may enhance growth and reproduction of both suspension and deposit feeding species.

Sensitivity assessment Resistance is '**High**' as no significant negative effects are identified and potential benefits from increased food resources may occur, based on expert judgement, utilising evidence of species traits and distribution. Resilience is also '**High**' as no recovery is required under the likely impacts. Sensitivity of the biotope is therefore, assessed as '**Not Sensitive**'.

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

The biotope is located mainly in soft wet mud with a fine sand fraction, on the mid and lower shore of sheltered estuaries (Connor *et al.*, 2004). These locations would be likely to experience some redistribution of fine material during tidal cycles. Although the biotope occurs in sheltered locations some mixing from wave action may also be expected.

Powilleit *et al.*, (2009) studied the response of the polychaete *Nephtys hombergii* to smothering. This species successfully migrated to the surface of 32-41 cm deposited sediment layer of till or sand/till mixture and restored contact with the overlying water. The high escape potential could partly be explained by the heterogeneous texture of the till and sand/till mixture with 'voids'. While crawling upward to the new sediment surfaces burrowing velocities of up to 20 cm/day were recorded for *Nephtys hombergii*. Similarly, Bijkerk (1988, results cited from Essink 1999) indicated that the maximal overburden through which species could migrate was 60 cm through mud for *Nephtys* and 90 cm through sand. No further information was available on the rates of survivorship or the time taken to reach the surface.
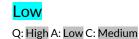
Limecola balthica is able to burrow both vertically and horizontally through the substratum. It is

likely that *Limecola balthica* is not sensitive to smothering by a layer of sediment 5 cm thick as it is a mobile species able to burrow upwards and surface from a depth of 5 - 6 cm (Brafield & Newell, 1961; Brafield, 1963; Stekoll *et al.*, 1980). Turk and Risk (1981) investigated the effect of experimentally induced sedimentation (through fences and boxes that induced sediment deposition on intertidal mudflats in the Bay of Fundy), of 1-3.5cm at a rate of 1.9-10.2 cm/month. The results showed that *Limecola balthica* was generally unaffected.

Sensitivity assessment. Based on the available evidence, resistance of the characterizing species *Nephtys hombergii* and *Limecola balthica* is likely to be 'High', and biotope resistance is assessed as 'High' although some short-term changes in sediments may occur, resilience is also '**High**' and sensitivity is assessed as '**Not Sensitive**'. Confidence in this assessment is lower as the assessment is based on traits of the species characterizing the biotope and the relevant direct case studies present examples where impacts are not from single discrete events.

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

Limited evidence was found on responses of characterizing species to a deposition of up to 30cm of fine material. A thick layer of sediment has a smothering effect and in most instances buried species will die although some polychaetes can escape up to 90cm of burial In response to nourishment (Speybroek *et al.*, 2007, references therein). Peterson *et al.* (2000) found that the dominant macrofauna were reduced by 86-99% 5-10 weeks after the addition of sediment that was finer than the original sediments but with a high shell content. The pressure benchmark (30 cm deposit) represents a significant burial event and the deposit may remain for some time in sheltered habitats. Some impacts on some characterizing species may occur and it is considered unlikely that significant numbers of the population could reposition, based on Bolam (2011). 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) (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. Placement of the deposit will, therefore, result in a defaunated habitat until the deposit is recolonized

Powilleit *et al.*, (2009) studied the response of the polychaete *Nephtys hombergii* to smothering. This species successfully migrated to the surface of 32-41 cm deposited sediment layer of till or sand/till mixture and restored contact with the overlying water. The high escape potential could partly be explained by the heterogeneous texture of the till and sand/till mixture with 'voids'. While crawling upward to the new sediment surfaces burrowing velocities of up to 20 cm/day were recorded for *Nephtys hombergii*. Similarly, Bijkerk (1988, results cited from Essink 1999) indicated that the maximal overburden through which species could migrate was 60 cm through mud for *Nephtys* and 90 cm through sand. No further information was available on the rates of survivorship or the time taken to reach the surface.

Limecola balthica is able to burrow both vertically and horizontally through the substratum. It is likely that *Limecola balthica* is not sensitive to smothering by a layer of sediment 5 cm thick as it is a mobile species able to burrow upwards and surface from a depth of 5 - 6 cm (Brafield & Newell, 1961; Brafield, 1963; Stekoll *et al.*, 1980). Turk and Risk (1981) investigated the effect of experimentally induced sedimentation (through fences and boxes that induced sediment

deposition on intertidal mudflats in the Bay of Fundy), of 1-3.5 cm at a rate of 1.9-10.2 cm/month. The results showed that *Limecola balthica* was generally unaffected.

Bolam (2011) showed that *Streblospio shrubsolii* vertical migration capability was reduced by deposition of just 6cm simulated dredged material. *Tubificoides benedii* showed good recovery following deposition of material. Rosenberg (1977) found recruitment of benthic species was heavily reduced in the vicinity of a dredged area, suggesting the increased turbidity was likely to be responsible. Contamination, for example from hydrocarbons may be an added impact if deposited sediment has been carried from a source of pollution such as oil drilling sites (Gray *et al.*, 1990). These impacts are considered in the 'pollution and other chemical changes' section.

Sensitivity assessment. Deposition of up to 30cm of fine material is likely to provide different impacts for the different species characterizing the biotope. The characterizing species *Nephtys hombergii* is likely to burrow and reposition through a fine sediment overburden at the pressure benchmark but other species such as *Steblospio shrubsolii* and *Limecola balthica* may be smothered. The addition of fine sediments will also alter the sediment habitat. Biotope resistance is, therefore, assessed as '**Low**' and resilience is assessed as '**High**' (although this may be prolonged where sediments are not rapidly removed and habitat recovery times are prolonged). Biotope sensitivity is assessed as **'Low'.**

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

No evidence was returned on the impact of litter on characterizing species for this biotope, although studies show impacts from ingestion of micro plastics by sub surface deposit feeding worms (*Arenicola marina)* and toxicants present in cigarette butts have been shown to impact the burrowing times and cause DNA damage in ragworms *Hediste diversicolor*.

Litter, in the form of cigarette butts has been shown to have an impact on Ragworms. *Hediste diversicolor* showed increased burrowing times, 30% weight loss and a >2 fold increase in DNA damage when exposed to water with toxicants (present in cigarette butts) in quantities 60 fold lower than reported from urban run-off (Wright *et al.*, 2015). Studies are limited on impacts of litter on infauna and this UK study suggests health of infauna populations are negatively impacted by this pressure.

Studies of sediment dwelling, sub surface deposit feeding worms, a trait shared by species abundant in this biotope, showed negative impacts from ingestion of micro plastics. For instance, *Arenicola marina* ingests micro-plastics that are present within the sediment it feeds within. Wright *et al.* (2013) carried out a laboratory study that showed the presence of micro-plastics (5% UPVC) significantly reduced feeding activity when compared to concentrations of 1% UPVC and controls. As a result, *Arenicola marina* showed significantly decreased energy reserves (by 50%), took longer to digest food, and as a result decreased bioturbation levels which would be likely to impact colonisation of sediment by other species, reducing diversity in the biotopes the species occurs within.

Sensitivity assessment. Evidence and confidence in the assessment is limited and this pressure is **'Not assessed'.**

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

No evidence was found on effects of electric and magnetic fields on the characterizing species.

Electric and magnetic fields generated by sources such as marine renewable energy device/array cables may alter behaviour of predators and affect infauna populations. Evidence is limited and occurs for electric and magnetic fields below the benchmark levels, confidence in evidence of these effects is very low.

Field measurements of electric fields at North Hoyle wind farm, North Wales recorded 110μ V/m (Gill *et al.* 2009). Modelled results of magnetic fields from typical subsea electrical cables, such as those used in the renewable energy industry produced magnetic fields of between 7.85 and 20 μT (Gill *et al.* 2009; Normandeau *et al.* 2011). Electric and magnetic fields smaller than those recorded by in field measurements or modelled results were shown to create increased movement in thornback ray *Raja clavata* and attraction to the source in catshark *Scyliorhinus canicular* (Gill *et al.* 2009).

Flatfish species which are predators of many polychaete species including dab *Limanda limanda* and sole *Solea solea* have been shown to decrease in abundance in a wind farm array or remain at distance from wind farm towers (Vandendriessche *et al.*, 2015; Winter *et al.* 2010). However, larger plaice increased in abundance (Vandendriessche *et al.*, 2015). There have been no direct causal links identified to explain these results.

Sensitivity assessment. 'No evidence' was available to complete a sensitivity assessment, however, responses by flatfish and elasmobranchs suggest changes in predator behaviour are possible. There is currently no evidence but effects may occur on predator prey dynamics as further marine renewable energy devices are deployed, these are likely to be over small spatial scales and not impact the biotope.

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

Species within the biotope can probably detect vibrations caused by noise and in response may retreat into the sediment for protection. However, at the benchmark level the community is unlikely to be sensitive to noise and this pressure is considered **'Not relevant'.**

Introduction of light or shading   High   High   Not sensitive
                                        Q: Low A: NR C: NR   Q: High A: High C: High   Q: Low A: Low C: Low

There is no direct evidence of effects of changes in incident light on the characterizing species of this biotope. All characterizing species live in the sediment and do not rely on light levels directly to feed or find prey so limited direct impact is expected. As this biotope is not characterized by the presence of primary producers it is not considered that shading would alter the character of the habitat directly.

More general changes to the productivity of the biotope may, however, occur. Beneath shading structures there may be changes in microphytobenthos abundance. Littoral muddy sands support microphytobenthos on the sediment surface and within the sediment. The microphytobenthos

consists of unicellular eukaryotic algae and cyanobacteria that grow within the upper several millimetres of illuminated sediments, typically appearing only as a subtle brownish or greenish shading. Mucilaginous secretions produced by these algae may stabilise fine substrata (Tait & Dipper, 1998).

Shading will prevent photosynthesis leading to death or migration of sediment microalgae altering sediment cohesion and food supply to higher trophic levels. The impact of these indirect effects is difficult to quantify.

Sensitivity assessment. Based on the direct impact, biotope resistance is assessed as '**High**' and resilience is assessed as '**High**' (by default) and the biotope is considered to be '**Not sensitive'**.

Barrier to species movement	High	High	Not sensitive
	Q: Low A: NR C: NR	Q: High A: High C: High	Q: Low A: Low C: Low

Barriers that reduce the degree of tidal excursion may alter larval supply to suitable habitats from source populations. Barriers may also act as stepping stones for larval supply over greater distances (Adams et al., 2014). Conversely, the presence of barriers at brackish waters may enhance local population supply by preventing the loss of larvae from enclosed habitats to environments, which are unfavourable, reducing settlement outside of the population. If a barrier (such as a tidal barrier) incorporated renewable energy devices such as tidal energy turbines, these devices may affect hydrodynamics and so migration pathways for larvae into and out of the biotope (Adams *et al.*, 2014). Evidence on this pressure is limited.

Sensitivity assessment. Resistance to this pressure is assessed as '**High**' and resilience as '**High**' by default. This biotope is therefore considered to be **'Not sensitive'**.

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

'**Not relevant'** to seabed habitats. NB. Collision by interaction with bottom towed fishing gears and moorings are addressed under 'surface abrasion'.

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

Characterizing species may have some, limited, visual perception. As they live in the sediment the species will most probably not be impacted at the pressure benchmark and this pressure is considered **'Not relevant'.**

🐚 Biological Pressures

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

The key characterizing species in the biotope are not cultivated or likely to be trans-located. This pressure is therefore considered '**Not Relevant**'.

Introduction or spread of invasive non-indigenous species

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

Intertidal sediments may be colonized by a number of invasive non-indigenous species. Invasive species that alter the character of the biotope or that predate on characterizing species are most likely to result in significant impacts. Intertidal flats may be colonized by the invasive non-indigenous species *Crepidula fornicata* and the Pacific oyster *Magallana gigas*. The two species have not only attained considerable biomasses from Scandinavian to Mediterranean countries but have also generated ecological consequences such as alterations of benthic habitats and communities and food chain changes (OSPAR, 2009b).

In the Wadden Sea, the Pacific oyster *Magallana gigas* has colonized intertidal flats (Smaal *et al*., 2005). This species consumes pelagic larvae reducing recruitment (Smaal *et al*., 2005).   The most severe effects are likely to occur from impacts on sediment, where *Magallana gigas* create reefs on sedimentary flats that will prevent recruitment of juveniles and will restrict access of infauna to the sediment-water interface impacting respiration and feeding of bivalves such as *Limecola balthica* and polychaetes such as *Steblospio shrubsolii*. Burrowing infauna such as *Nephtys hombergii* and oligochaetes may persist within sediments but the overall character of the mixed sediment biotope would be altered.

The Manila clam (*Tapes philippinarium*), which was introduced to Poole Harbour for aquaculture in 1998, has become a naturalised population on the intertidal mudflats (occurring at densities of 60 clams/m2 in some locations within the harbour (Jensen *et al*. 2004, cited in Caldow *et al*. 2007). Densities of *Cerastoderma edule* and *Abra tenuis* increased following the introduction of the Manila clam but the abundance of *Limecola balthica* declined (Caldow *et al*., 2005), although the decline of these species may have been caused by tri-butyl tin pollution (Langston *et al*., 2003) and may have facilitated the naturalization of the Manila clam.

The predatory veined whelk (*Rapana venosa*) and *Hemigrapsus takinei* are not established in the UK (although *Hemigrapsus takinei* has been recorded at two locations) could become significant predators of *Cerastoderma edule* and other species associated with the biotope in the future.

Sensitivity assessment. Intertidal muddy sands may be exposed to invasive species which can alter the character of the habitat (primarily *Crepidula fornicata* at the sublittoral fringe and *Magallana gigas*) leading to re-classification of this biotope, the biotope is considered to have '**Low**' resistance and '**Very low**' recovery (unless invasive species are removed). Biotope sensitivity is, therefore, assessed as '**High**'.

Introduction of microbial pathogens

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

No evidence on the effect of microbial pathogens or metazoan disease vectors was found for *Nephtys hombergii*. *Limecola balthica* in Delaware Bay, north-east USA, was found to host *Perkinsus* genus pathogens *Perkinsus andrewsi* and *Perkinsus marinus* (Lindsay *et al*., 2007). *Cerastoderma edule* has been reported to host approximately 50 viruses, bacteria and fungi, and including turbellaria,

digeneans and cestodes (Longshaw & Malham, 2013).

Sensitivity assessment. Based on the evidence for the *Limecola balthica* and *Cerastoderma edule*, it is likely that parasitic infection may indirectly alter the species composition of the biotope. Although less evidence was returned for the characterizing mollusc species *Limecola balthica*, similar impacts from introduction of pathogens are likely to be experienced for this species. Resistance is assessed as **'Medium**', Resilience as '**High'** and Sensitivity as **'Low'**.

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

Nephtys hombergii is directly removed through commercial bait digging and by recreational anglers and abundance significantly decreased in areas of the Solent, UK, where bait digging (primarily for *Nereis virens*) had occurred (Watson *et al.* 2007).

Recovery of *Nephtys hombergii* has been assessed to be very high as re-population would occur initially relatively rapidly via adult migration and later by larval recruitment. Dittman *et al.* (1999) observed that *Nephtys hombergii* was amongst the macrofauna that colonized experimentally disturbed tidal flats within two weeks of the disturbance that caused defaunation of the sediment. However, if sediment is damaged recovery is likely to be slower, for instance *Nephtys hombergii* abundance was reduced by 50% in areas where tractor towed cockle harvesting was undertaken on experimental plots in Burry inlet, south Wales, and had not recovered after 86 days (Ferns *et al.*, 2000).

Hiddink (2003) found that the density of Limecola balthica (as *Macoma balthica*) was reduced in areas in the Wadden sea (Netherlands) that had experienced suction dredging for cockles, which removes the surface sediment, The disturbance to the sediment also appeared to leave the habitat less suitable for settlement of young *Limecola balthica* (Hiddink, 2003). This study provides evidence of loss of a characterizing species from the biotope and that recovery is unlikely to occur until the sediment characteristics have returned to pre-impact conditions. Removal of target species such as cockles *Cerastoderma edule* or bait digging for *Arenicola marina* is likely to impact the biotope. The extent of the impact will depend on the fishing / removal method and spatial extent.

Sensitivity assessment. Resistance is '**Low**' due to direct removal of a characterising species, that on commercial scales can remove a large proportion of the population. Resilience is assessed as **'High'** as regions that are not regularly harvested may recover rapidly but it should be noted that continued harvesting will impact the population. Sensitivity is assessed as '**Low'**. It is important to consider that the spatial extent and duration of harvesting is important to consider when assessing this pressure as smaller scale extraction may not impact the entire extent of the biotope but greater scale extraction over a long period could cause more severe impacts.

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

Hiddink (2003) showed that the density of *Limecola balthica* (as *Macoma balthica*) was reduced in areas in the Wadden sea (Netherlands) that had experienced suction dredging for cockles, which removes the surface sediment. The disturbance to the sediment also appeared to leave the habitat less suitable for settlement of young *Limecola balthica* (Hiddink, 2003). This study provides

evidence of loss of a characterizing species from the biotope and that recovery is unlikely to occur until the sediment characteristics have returned to pre-impact conditions. Removal of target species such as cockles *Cerastoderma edule* or bait digging for *Arenicola marina* is likely to impact the biotope. The extent of the impact will depend on the fishing / removal method and spatial extent.

McLusky *et al.* (1983) found that *Limecola balthica* (as *Macoma balthica*) populations were unaffected in dug areas, following bait digging for lugworms suggesting the biotope would recover from this impact if it occurred over a limited spatial scale.

Incidental removal of the characterizing species would alter the character of the biotope and the delivery of ecosystem services such as secondary production and bioturbation. Populations of characterizing species, such as *Nephtys hombergii* and *Limecola balthica* provide food for macroinvertebrates fish and birds and their loss could alter the provision of food to these species.

Sensitivity assessment. Removal of the characterizing species would alter the character of the biotope. Resistance is therefore assessed as **'Low'** and resilience as '**High**', so sensitivity is categorized as '**Low**'.

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