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

Aphelochaeta marioni and *Tubificoides* spp. in variable salinity infralittoral mud

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

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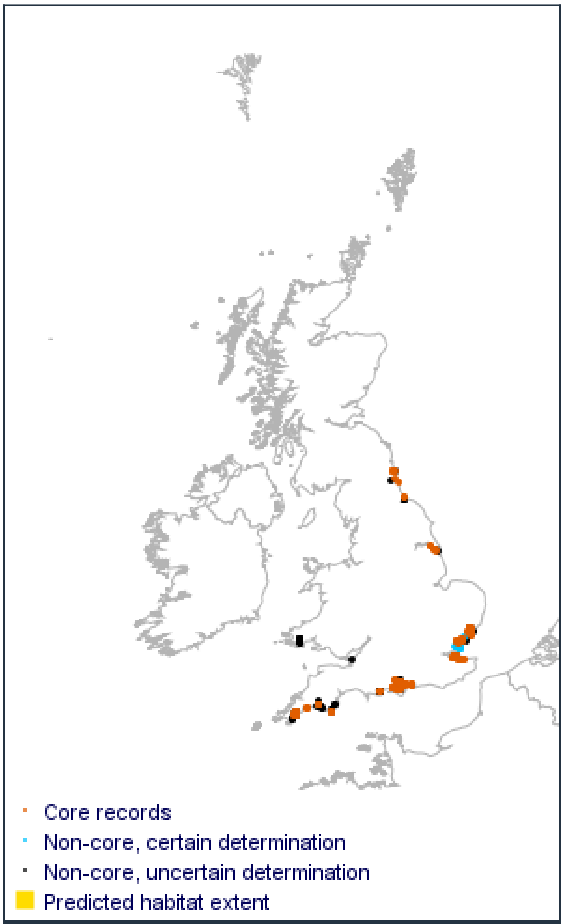

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Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Eliane De-Bastos & Dr Keith Hiscock **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A5.322	*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud
JNCC 2015	SS.SMu.SMuVS.AphTubi	*Aphelochaeta marioni* and *Tubificoides* spp. in variable salinity infralittoral mud
JNCC 2004	SS.SMu.SMuVS.AphTubi	*Aphelochaeta marioni* and *Tubificoides spp.* in variable salinity infralittoral mud
1997 Biotope	SS.IMU.EstMu.AphTub	*Aphelochaeta marioni* and *Tubificoides spp.* in variable salinity infralittoral mud

Description

Variable salinity cohesive muddy sediment (sometimes with some coarser material) dominated by the polychaete *Aphelochaeta marioni* (or other *Aphelochaeta* species e.g. *Aphelochaeta amplivasatus*) and the oligochaete *Tubificoides* spp.. These taxa are generally accompanied by *Nephtys hombergii* whilst the polychaetes *Capitella capitata* and *Melinna palmata* may also occur in high numbers in some areas. Other members of the cirratulid polychaete group e.g. *Caulleriella zetlandica* and *Tharyx* spp. may also occur in high numbers, sometimes replacing *Aphelochaeta marioni* as the dominant polychaete. However, there is still inconsistency in the identification of the cirratulid group which is further compounded by fragmentation during sample processing. This biotope is very common in stable muddy environments and may extend from reduced salinity to fully marine conditions (Information taken from Connor *et al*., 2004).

Depth range

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Additional information

None

Listed By

- none -

Further information sources

Search on:

JNCC

Habitat review

Ecology

Ecological and functional relationships

- The biotope is characterized by tube-building or burrow-living polychaetes and by oligochaetes, with errant polychaetes foraging in the surrounding and underlying sediment.
- Mobile, carnivorous polychaetes, including *Nephtys hombergi*, *Anaitides* spp., *Eteone longa*, and *Pholoe* spp., predate the smaller annelids and crustaceans.
- The dominant tube-builders are the deposit feeding polychaetes *Polydora ciliata* and *Lanice conchilega*. In areas of mud, the tubes built by *Polydora ciliata* can agglomerate and form layers of mud an average of 20 cm thick, occasionally up to 50 cm (Daro & Polk, 1973).
- The feeding activities of high densities of *Polydora ciliata* may inhibit the establishment of other benthic species by removing settling and developing larvae (Daro & Polk, 1973).
- In some examples of the biotope, the tube-building, suspension feeding amphipod *Ampelisca* sp. and the burrowing *Corophium volutator* are present.
- The amphipods and the infaunal annelid species in the biotope probably interfere strongly with each other. Adult worms probably reduce amphipod numbers by disturbing their burrows and tubes, while high densities of amphipods can prevent establishment of worms by consuming larvae and juveniles (Olafsson & Persson, 1986).
- Some examples of the biotope contain a number of infaunal bivalve species, including *Abra alba*, *Abra nitida* and *Kurtiella bidentata*, which probably both deposit feed and suspension feed depending on local environmental conditions.
- Foraging species such as *Carcinus maenas* and *Crangon crangon* may feed selectively and influence the composition of the biotope.

Seasonal and longer term change

The biotope is present throughout the year with the possibility of some seasonal variation in numbers of each species. Hall & Frid (1998) found that colonization by many of the polychaetes associated with this biotope did not vary significantly with season, although recruitment of *Tubificoides benedii* and *Ophyrotrocha hartmanni* did vary significantly with season.

Habitat structure and complexity

- Structural complexity is provided by the many tube building species in the biotope. The tubes built by *Polydora ciliata* for example are embedded in the sediment and the ends extend a few millimetres above the substratum surface. The mats of agglomerated sediment may be up to 50 cm thick.
- Additional structural complexity is provided by the burrows of infauna although these are generally simple. Most species living within the sediment are limited to the area above the anoxic layer, the depth of which will vary depending on sediment particle size and organic content. Underlying sediments may also become oxygenated by the activities of amphipods within their tubes (Mills, 1967), burrowing bivalves and polychaetes.

Productivity

Production in IMU.Aph.Tub is mostly secondary, derived from detritus and organic material. Where the biotope occurs in shallow subtidal waters, some primary production comes from benthic microalgae (microphytobenthos e.g. diatoms, flagellates and euglenoides) and water column phytoplankton. In all cases, the benthos is supported predominantly by pelagic production and by detrital materials emanating from the coastal fringe (Barnes & Hughes, 1992). The amount of planktonic food reaching the benthos is related to:

- depth of water through which the material must travel;
- magnitude of pelagic production;
- proximity of additional sources of detritus, and the
- extent of water movement near the sea bed, bringing about the renewal of suspended supplies (Barnes & Hughes, 1992).

Food becomes available to deposit feeders by sedimentation on the substratum surface and by translocation from the water column to the substratum through production of pseudofaeces by suspension feeders.

Productivity in the biotope is expected to be high. Many of the characterizing species are likely to have a short lifespan, grow to maturity quickly and have multiple generations per year. The sediment in the biotope may be nutrient enriched due to proximity to anthropogenic nutrient sources such as sewage outfalls or eutrophicated rivers.

Recruitment processes

Limited information has been found on species in the biotope and only characterizing species have been specifically researched.

- The lifecycle of *Aphelochaeta marioni* varies according to environmental conditions. In Stonehouse Pool, Plymouth, *Aphelochaeta marioni* (studied as *Tharyx marioni*) spawned in October and November (Gibbs, 1971) whereas in the Wadden Sea, Netherlands, spawning occurred from May to July (Farke, 1979). The embryos developed lecithotrophically and hatched in about 10 days (Farke, 1979). Under stable conditions, adult and juvenile *Aphelochaeta marioni* will disperse by burrowing (Farke, 1979).
- The spawning period for *Polydora ciliata* in northern England is from February until June and three or four generations succeed one another during the spawning period (Gudmundsson, 1985). After a week, the larvae emerge and are believed to have a pelagic life from two to six weeks before settling (Fish & Fish, 1996). The larvae settle preferentially on substrates covered with mud (Lagadeuc, 1991).
- *Nephtys hombergi* exhibits variable spawning success with failures in some years (Olive *et al.*, 1997).
- The mating system of amphipods is polygynous and several broods of offspring are produced, each potentially fertilized by a different male. There is no larval stage and embryos are brooded in a marsupium, beneath the thorax. Embryos are released as sub-juveniles with incompletely developed eighth thoracopods and certain differences in body proportions and pigmentation. Dispersal is limited to local movements of these sub-juveniles and migration of the adults and hence recruitment is limited by the presence of local, unperturbed source populations (Poggiale & Dauvin, 2001). Dispersal of sub-juveniles may be enhanced by the brooding females leaving their tubes and swimming to

uncolonized areas of substratum before the eggs hatch (Mills, 1967).

- The tube building polychaetes, e.g. *Pygospio elegans*, generally disperse via a pelagic larval stage (Fish & Fish, 1996) and therefore recruitment may occur from distant populations (Boström & Bonsdorff, 2000). However, dispersal of some of the infaunal deposit feeders, such as *Scoloplos armiger*, occurs through burrowing of the benthic larvae and adults (Beukema & De Vlas, 1979; Fish & Fish, 1996). Recruitment must therefore occur from local populations or by longer distance dispersal during periods of bedload transport. Recruitment is therefore likely to be predictable if local populations exist, but patchy and sporadic otherwise.

Time for community to reach maturity

The community is dominated by fast growing opportunistic species and the community most likely reaches maturity within one year of space becoming available. In an experimental study investigating recovery of a range of species characteristically found in this biotope after copper contamination, Hall & Frid (1995) found that recovery took up to a year. However, Hall & Frid (1998) found that colonization by many of the polychaetes associated with this biotope did not vary significantly with season, although recruitment of *Tubificoides benedii* and *Ophyrotrocha hartmanni* did vary significantly with season.

Additional information

None

Preferences & Distribution

Habitat preferences

Depth Range	
Water clarity preferences	
Limiting Nutrients	No information found
Salinity preferences	
Physiographic preferences	
Biological zone preferences	
Substratum/habitat preferences	
Tidal strength preferences	
Wave exposure preferences	
Other preferences	No information found

Additional Information

None

Species composition

Species found especially in this biotope

Rare or scarce species associated with this biotope

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Additional information

Nephtys hombergi and *Tubificoides* spp. have also been researched as a part of the sensitivity assessment although separate reviews have not yet (April 2002) been prepared. Four hundred and seventy two species have been recorded from this biotope by the Marine Nature Conservation Review (JNCC, 1999) although many in small numbers or in few examples.

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

SS.SMu.SMuVS.AphTubi is an infralittoral biotope occurring in sheltered, very sheltered and extremely sheltered areas with moderately strong and weak tidal streams (Connor *et al*., 2004). The biotope occurs in cohesive mud and sandy mud, possibly with shell debris and stones, in full and variable salinities. The biotope is dominated by the polychaete *Aphelochaeta marioni* (or other *Aphelochaeta* species e.g. *Aphelochaeta amplivasatus*) and oligochaete *Tubificoides* spp.. These taxa are generally accompanied by high numbers of other polychaetes.

SS.SMu.SMuVS.NhomTubi is a variable salinity biotope, occurring in soft infralittoral mud and sandy mud characterized by the polychaete *Nephtys hombergii* and oligochaetes of the genus *Tubificoides* (Connor *et al*., 2004). Other characterizing species that may be present are the polychaetes *Streblospio shrubsolii* and *Aphelochaeta marioni*, and the cumacean *Diastylis rathkei typica*.

SS.SMu.SMuVS.NhomTubi is found in areas of silt deposition in soft and sandy muds but may not form a stable habitat. It may be found adjacent to SS.SMu.SMuVS.AphTubi, separated by the abundance of *Aphelochaeta marioni* and its more cohesive sediments. SS.SMu.SMuVS.AphTubi and SS.SMu.SMuVS.NhomTubi and therefore assessed here as a group with the relevant physical and biological differences highlighted where necessary.

SS.SMu.SMuVS.AphTubi and SS.SMu.SMuVS.NhomTubi are dominated by the polychaete *Aphelochaeta marioni* and oligochaete *Tubificoides* spp., and *Nephtys hombergii* and oligochaete *Tubificoides* spp., respectively. These species are, therefore, the focus of this assessment. Other taxa present contribute to species richness and diversity but are not considered important characterizing, defining or structuring species and are not considered within the assessment. More information on these species can be found in other biotope assessments available on this website.

Resilience and recovery rates of habitat

Aphelochaeta marioni is a thin, thread like, segmented worm, typically between 2 and 3.5 cm in length, although individuals can reach 10 cm in length (Rayment, 2007a). It lives buried in the upper 4 cm of soft sediments, with the smaller animals nearer the surface. *Aphelochaeta marioni* can live up to 2-3 years and its lifecycle varies according to environmental conditions (Rayment, 2007a). In Stonehouse Pool, Plymouth Sound, *Aphelochaeta marioni* (studied as *Tharyx marioni*) spawned in October and November (Gibbs, 1971) whereas in the Wadden Sea, Netherlands, spawning occurred from May to July (Farke, 1979). Laboratory observation reported spawning occurring at night, with females that rose up into the water column with their tail end in the burrow, and shed eggs within a few seconds that sank to form puddles on the sediment (Farke, 1979). Fertilization was not observed, probably because the male does not leave the burrow. The embryos developed lecithotrophically and hatched in about 10 days (Farke, 1979). The newly hatched juveniles were ca 0.25 mm in length and immediately dug into the sediment. Where the sediment depth was not sufficient for digging, the juveniles swam or crawled in search of a suitable substratum (Farke, 1979). In the laboratory, juvenile mortality was high (ca 10% per month) and most animals survived for less than a year (Farke, 1979). In the Wadden Sea, the majority of the cohort reached maturity and spawned at the end of their first year, although some slower developers did not spawn until the end of their second year (Farke, 1979). However, the population of *Aphelochaeta marioni* in Stonehouse Pool spawned for the first time at the end of their second year (Gibbs, 1971). There was no evidence of a major post-spawning mortality and it was suggested that individuals may survive to spawn over several years. Gibbs (1971) found that the number of eggs laid varied from 24-539 (mean=197) and was correlated with the female's number of genital segments and, hence, female size and age.

Usually for oligochaetes, fertilization is internal and relatively few large eggs are shed directly into a cocoon that is secreted by the worm (Giere & Pfannkuche, 1982). Asexual reproduction is possible in some species by spontaneous fission (Giere & Pfannkuche, 1982). The naid oligochaete *Panais litoralis* can produce asexually producing clones, the rapid rate of increase (18 times population abundance in 3 months, Gillett *et al*., 2007) allows this species (which is sensitive to high temperatures, hypoxia and is exposed to predation due to shallow burial) to repopulate rapidly when conditions are favourable. However, few Tubificidae and Enchytraeidae produce asexually (Giere & Pfannkuche, 1982).

Tubificid populations tend to be large and to be constant throughout the year, although some studies have noticed seasonal variations (Giere & Pfannkuche, 1982). Many species, including *Tubificoides benedii* have a two-year reproductive cycle and only part of the population reproduces each season (Giere & Pfannkuche, 1982). Populations of *Tubificoides benedii* in the Fourth Estuary have not demonstrated clear seasonality in recruitment (Bagheri & McLusky, 1982), although mature *Tubificoides benedii* (as *Peloscolex benedeni*) in the Thames Estuary were reported to occur in December with a maximum in late February (Hunter & Arthur, 1978), breeding worms increased from April and maximum cocoon deposition was observed in July (Hunter & Arthur, 1978). Tubificids exhibit many of the traits of opportunistic species. It is dominant, often reaching huge population densities in coastal areas that are enriched in organic matter and is often described as an 'opportunist' species adapted to rapid environmental fluctuations and stress (Giere, 2006; Bagheri & McLusky, 1982). However, unlike other opportunist species it has a long lifespan (a few years, Giere, 2006), a prolonged reproductive period from reaching maturity to maximum cocoon deposition and exhibits internal fertilization with brooding rather than pelagic dispersal. These factors mean that recolonization is slower than for some opportunistic species such as *Capitella capitata* and nematodes which may be present in similar habitats.

Bolam & Whomersley (2003) observed faunal recolonization of fine sediments placed on saltmarsh as a beneficial use and disposal of fine grained dredged sediments. They found that tubificid oligochaetes began colonizing sediments from the first week following a beneficial use scheme involving the placement of fine-grained dredged material on a saltmarsh in south east England. The abundance of *Tubificoides benedii* recovered slowly in the recharge stations and required 18 months to match reference sites and those in the recharge stations prior to placement of sediments. The results indicate that some post-juvenile immigration is possible and that an *in situ* recovery of abundance is likely to require more than 1 year. Rapid recolonization has also been observed in the tubificid oligochaete *Baltidrilus costata (Tubifex costatus)* appeared in upper sediment layers in experimentally defaunated patches (4 m^2) after 3 weeks (Gamenick *et al*., 1996).

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. 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). Two larval cohorts were observed from *Nephtys hombergii* in Arachon Bay, France within one year (Mathivat-Lallier & Cazaux, 1991). Post-larvae settled directly in the intertidal area and again two distinct waves of recruitment were observed. These traits suggest the species is likely to require longer to recover than more opportunistic species.

Resilience assessment. The biotopes are dominated by fast growing opportunistic polychaetes and are likely to reach maturity within one year of space becoming available. Seasonal changes may, however, occur in the abundance of the fauna due to seasonal recruitment processes. For example, variation in abundance is very pronounced in the polychaete *Aphelochaeta marioni*. In the Wadden Sea, peak abundance occurred in January (71,200 individuals per m^2) and minimum abundance occurred in July (22,500 individuals per m^2), following maximum spawning activity between May and July (Farke, 1979). In general, there was little information found for *Tubificoides benedii*, but, taking into consideration the information above (particularly Bolam & Whomersley, 2003), this review considers that the recoverability of this species is generally high. Recovery of *Nephtys hombergii* is likely to occur over 1-2 years. Removal of the characterizing species *Aphelochaeta*, *Tubificoides* spp. and *Nephtys hombergii* would likely result in the biotopes being lost and reclassified. Where a disturbance event removes part of the community (resistance High, Medium or Low) and recruitment of the characterizing species is possible by adult migration or recruitment from the remaining members of the community, resilience is likely to be **High**. However, *Aphelochaeta marioni* has no pelagic phase in its lifecycle, and dispersal is limited to the slow burrowing of the adults and juveniles (Farke, 1979). So where the community is severely reduced (resistance None), recruitment is likely to depend on dispersal by hydrodynamic conditions. The low energy conditions experienced by SS.SMu.SMuVS.AphTubi may limit immediate recolonization. However, as long as the substratum nature of the biotope remains suitable for the settlement of recruits, the community is likely to reach maturity within 2-10 years, so resilience of SS.SMu.SMuVS.AphTubi is likely to be **Medium**. On the other hand, *Aphelochaeta* is less abundant in SS.SMu.SMuVS.NhomTubi and recovery of the biotope from severe defaunation (resistance None) will depend on successful recruitment of *Nephtys hombergii* and *Tubificoides* spp., which will be aided by more energetic conditions. Thus, recovery of SS.SMu.SMuVS.NhomTubi is still likely to be **High.**

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

Aphelochaeta marioni is distributed over a wide temperature range. It has been recorded from the Mediterranean Sea and Indian Ocean (Farke, 1979). Therefore, the species must be capable of tolerating higher temperatures than it experiences in Northern Europe. For example, Covazzi Harriague *et al.* (2007) reported *Aphelochate marioni* occurring in the Rapallo Harbour (Ligurian Sea, NW Mediterranean) at 24°C. Furthermore, *Aphelochaeta marioni* lives infaunally and so is likely to be insulated from rapid temperature change. An increase in temperature would be expected to cause some physiological stress but no mortality.

Deeper burrowing oligochaetes are protected from fluctuations in temperature by the overlaying sediments which dampen changes if poorly drained (Giere & Pfannkuche, 1982). Bamber & Spencer (1984) observed that *Tubificoide*s were dominant species in an area affected by thermal discharge in the River Medway estuary. Sediments were exposed to the passage of a temperature front of approximately 10°C between heated effluent and estuarine waters during the tidal cycles. *Tubificoides benedii* has increased in abundance in mudflat habitats in Jade Bay, North Sea between 1930 and 2009 (Schueckel & Kroencke, 2013). Climate warming as well as decreasing nutrient loads and species introductions have occurred in the region since the 1970s, suggesting the species may adapt to temperature increases at the benchmark level. *Tubificoides benedii* is considered an opportunist that is adapted to rapid environmental fluctuations and harsh conditions in estuaries (Gogina *et al.*, 2010), suggesting resistance would be high to this pressure at the benchmark level.

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 a 5°C increase in temperature in the 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 temperature for one month period, or 2°C for one year is likely to impact the timing of reproduction in these areas. A combination of environmental factors appears to influence timing (in particular spring tides), therefore, temperature may not be the most significant cue but evidence is limited to identify the significance of temperature in relation to other factors (or cues).

Sensitivity assessment. Typical surface water temperatures around the UK coast vary seasonally from 4-19°C (Huthnance, 2010). Most organisms in the biotopes are distributed to the north and south of Britain and Ireland and unlikely to be affected adversely by long-term temperature change. In addition, subtidal and especially infaunal species are likely to be protected from acute temperature change. Furthermore, the dominance of *Tubificoides* spp. when exposed to a heated effluent suggests that this genus would be highly resistant to an increase in temperature at the pressure benchmark. Resistance and resilience of the biotopes are therefore assessed as **High** and the biotopes are judged as **Not Sensitive**.

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

Aphelochaeta marioni is distributed over a wide temperature range. It has been recorded from the western Baltic Sea, south Atlantic Ocean and North Sea (Farke, 1979). Therefore the species must be capable of tolerating low temperatures. *Aphelochaeta marioni* lives buried in sediment and is therefore well insulated from decreases in temperature. In the Wadden Sea, the population was apparently unaffected by a short period of severe frost in I973 (Farke, 1979). Kędra *et al.* (2010) reported *Aphelochaete marioni* occurring in the Svalbard Archipelago where temperatures below zero may be experienced in the winter. A decrease in temperature would be likely to cause some physiological stress but no mortality.

Most littoral oligochaetes, including tubificids, can survive freezing temperatures and can survive in frozen sediments (Giere & Pfannkuche, 1982). *Tubificoides benedii* (studied as *Peloscolex benedeni*) recovered after being frozen for several tides in a mudflat (Linke, 1939).

Nephtys hombergii are found as far north as the Barents Sea, and would be expected to be resistant to a 5°C decrease in temperature 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 temperature for a one month period, occurring in winter, or 2°C for one year are likely to impact spawning success.

Sensitivity assessment. Typical surface water temperatures around the UK coast vary seasonally from 4-19°C (Huthnance, 2010). Based on the evidence presented, *Aphelochaeta marioni*, *Tubificoides benedii* 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 populations and may be compensated by later spawning events. Resistance and resilience are therefore assessed as **High** and the biotopes judged as **Not Sensitive**.

Salinity increase (local)	High Q: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High

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 also adjust.

Populations of *Aphelochaeta marioni* inhabit the open coast where seawater is at full salinity. Covazzi Harriague *et al.* (2007) reported *Aphelochaeta marioni* in the Rapallo Harbour (Ligurian Sea, NW Mediterranean) at salinities above 38 psu. Farke (1979) studied the effects of changing salinity on *Aphelochaeta marioni* (studied as *Tharyx marioni*) in a microsystem in the laboratory. Over several weeks, the salinity in the microsystem was increased from 25-40 psu and no adverse reaction was noted. However, when individuals were removed from the sediment and displaced to a new habitat, they only dug into their new substratum if the salinities in the two habitats were similar. If the salinities differed by 3-5 psu, the worms carried out random digging movements, failed to penetrate the sediment and died at the substratum surface after a few hours. This would suggest that *Aphelochaeta marioni* can tolerate salinity changes when living infaunally but may not resist an increase in salinity when removed from its habitat.

Oligochaete dominated biotopes are recorded from a range of salinity regimes from full (LS.LSa.MoSa.Ol; LS.LSa.MoSa.Ol.FS), variable (SS.SMu.SMuVS.CapTubi) to low (SS.SMu.SMuVS.LhofTtub) habitats (Connor *et al*., 2004). The species characterizing these biotopes are likely to vary. Giere & Pfannkuche (1982) identified how species change over a hypothetical salinity gradient with marine stenohaline species present at full salinities replaced by more euryhaline oligochaete species including *Tubificoides benedii* and *Tubificoides pseudogaster*. Studies in the Rhine delta have found that *Tubificoides benedii* is tolerant of a range of salinities (Verdonschot *et al*., 1982).

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 (1971b) observed that species with pelagic larvae or a free-swimming phase, including *Nephtys hombergii* 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. *Nephtys hombergii* may still be found in fully marine locations 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*.

Sensitivity assessment. Based on that all species occur in greater salinities than those that occur in these biotopes, the biological assemblages associated with the biotopes are considered to have **High** resistance and **High** resilience and is therefore considered to be **Not Sensitive** to an increase in salinity at the pressure benchmark level.

Salinity decrease (local)	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

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.

Aphelochaeta marioni thrives in estuaries and is, therefore, likely to be tolerant of decreases in salinity. It has been recorded from brackish inland waters in the southern Netherlands with a salinity of 16 psu, but not in areas permanently exposed to lower salinities (Wolff, 1973). However, it also penetrates into areas exposed to salinities as low as 4 psu for short periods at low tide when freshwater discharge from rivers is high (Farke, 1979). In the Severn Estuary, *Aphelochaeta marioni* (studied as *Tharyx marioni*) characterized the faunal assemblage of very poorly oxygenated, poorly sorted mud with relatively high interstitial salinity (Broom *et al*., 1991).

Nephtys hombergii is considered to be a brackish water species, and has been reported to extend in to 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 and localized densities would decline.

In Ria de Averio, western Portugal, *Tubificoides benedii* characterized communities in estuarine sample sites further upstream with lower salinity, suggesting a high resistance to a decrease in salinity (Rodrigues *et al.*, 2011).

Overall, the important characterizing species are likely to tolerate a short-term change in salinity from e.g. variable to low salinity and a long-term change from variable to reduced salinity. The species richness of the biotopes may decline but the biotopes will probably not be adversely affected.

Sensitivity assessment. Records indicate SS.SMu.SMuVS.AphTubi occurs in areas of full (30-35 ppt) and variable (18-35 ppt) salinities, whereas SS.SMu.SMuVS.NhomTubi occurs in areas of variable (18-35 ppt) salinity (Connor *et al.*, 2004). *Nephtys hombergii* is possibly the most sensitive to the lowest salinity levels within the 'low' salinity category, although as a mobile species, it will be resistant through being able to move lower down the shore or away from freshwater run-off. The remaining characterizing species *Aphelochaeta marioni* and *Tubificoides* spp. occur in estuarine areas experiencing low salinities, so are therefore likely to resist a decrease in salinity at the pressure benchmark level. Resistance of the biotopes is therefore assessed as **High** and resilience as **High** (by default), and the biotopes are considered **Not Sensitive** to a decrease in salinity at the pressure benchmark level.

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

The hydrographic regime is an important structuring factor in sedimentary habitats. An increase in water flow rate is not likely to affect *Nephtys hombergii*, *Aphelochaeta marioni* and *Tubificoides* spp. and other characterizing species as they live infaunally. The most damaging effect of increased flow rate 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 resuspending 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 resuspended) (Coates *et al.*, 2014). Species such as *Tubificoides benedii* and other opportunist polychaetes that tolerate coarser particle size will possibly increase in abundance. *Aphelochaeta marioni* has been recorded in the Wadden Sea with flow rates up to 0.45 m/s (Compton *et al.*, 2013), and in the Westerscheld estuary (SW Netherlands) where spring current velocities vary between 0.1-0.58 m/s (Van Colen *et al.*, 2010a).

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.

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). Although having a smaller grain size than sand, clays and silts require greater critical erosion velocities because of their cohesiveness. The biotopes occur most often in weak, moderately strong and strong tidal streams (Connor *et al.*, 2004), suggesting the species characterizing the biotopes can adapt to a range of tidal currents, aided by each species burrowing traits. A change in water flow rate at the pressure benchmark level of 0.1-0.2 m/s is considered to fall within the range of flow speeds experienced by populations in the middle of their range. Resistance and resilience are, therefore, assessed as **High** and the biotopes considered **Not Sensitive** to a change in water flow at the pressure benchmark level.

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

The biotopes occur in the infralittoral so that only the upper extent of shallow examples are likely to be emersed on extreme low tides. 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 biotopes to extend their upper limits, where suitable substrata exist.

Opportunistic, deposit feeding polychaetes and oligochaetes, such as *Aphelochaeta marioni* and *Tubificoides benedii* are likely to tolerate stressful conditions, and often out-compete more sensitive species in intertidal 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 10 cm, shows resistance to hypoxia and is 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 biotopes are covered by the sea is likely to result in increased abundance of *Tubificoides benedii*.

Sensitivity assessment. Some mortality of the characterizing species is likely to occur because of emergence regime changes. Resistance is therefore assessed as **Medium** and resilience is likely to be **High**, so the biotopes are considered to have **Low** sensitivity to emergence regime changes at the pressure benchmark level.

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

Strong wave action is likely to cause damage or withdrawal of delicate feeding and respiration structures resulting in loss of feeding opportunities and compromised growth for the characterizing species. Decreases in wave exposure may influence the supply of particulate matter because wave action may have an important role in resuspending the sediment. Furthermore, *Aphelochaeta marioni* characteristically inhabits soft sediments in sheltered areas (Broom *et al.*, 1991), so individuals may be damaged or dislodged by scouring from sand and gravel mobilized by increased wave action.

Disturbance of sediment by waves may reduce oligochaete abundance (Giere, 1977) and oligochaetes may be absent from very wave exposed shores (Giere & Pfannkuche, 1982).

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.

Sensitivity assessment. Hydrographic regimes are an important structuring factor in sedimentary habitats, and an increase in wave exposure could result in fine sediments being eroded (Hiscock, 1983), resulting in the likely reduction of the habitat and a decrease in food availability. Some erosion will occur naturally and storm events may be more significant in loss and damage of the substratum than changes in wave height at the pressure benchmark. 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 level may be low for the biotopes, as they are limited to sheltered locations. Increases in wave action may therefore remain within the limits of the species tolerances but factors such as sediment redistribution may alter the physical biotopes. The biotopes are found in moderately exposed, sheltered, very sheltered and extremely sheltered sites (Connor *et al.*, 2004) and a change at the benchmark level is likely to fall within the range experienced by the mid-range examples. The biotopes are therefore considered to have **High** resistance to changes at the pressure benchmark, where these do not lead to increased erosion of the substratum. Resilience is therefore assessed as **High** and the biotopes are considered to be **Not Sensitive** at the pressure benchmark.

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.

Evidence suggests that polychaetes are fairly resistant to the effects of heavy metals (Bryan, 1984). *Aphelochaeta marioni* is tolerant of heavy metal contamination occurring in the heavily polluted Restronguet Creek (Bryan & Gibbs, 1983) and it is also an accumulator of arsenic (Gibbs *et al.*, 1983). *Nephtys hombergii* is also recorded in Restronguet Creek. Rygg (1985) classified *Tubificoides* spp. as highly tolerant species, common at the most copper polluted stations (>200 mg/kg) in Norwegian fjords.

Taking account of the variable salinity conditions that affect these biotopes (in general, for estuarine animals, heavy metal toxicity increases as salinity decreases and temperature increases: McLusky *et al.*, 1986), it seems possible that some polychaete species, at least in the biotopes, might be adversely affected by high contamination by heavy metals.

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.

Cirratulids seem to be mostly immune to oil spills, probably because their feeding tentacles are protected by a heavy secretion of mucus (Suchanek, 1993). This is supported by observations of *Aphelochaeta marioni* following the *Amoco Cadiz* oil spill in March, 1978 (Dauvin, 1982, 2000). Prior to the spill, *Aphelochaeta marioni* (studied as *Tharyx marioni*) was present in very low numbers in the Bay of Morlaix, western English Channel. Following the spill, the level of hydrocarbons in the sediment increased from 10 mg/kg dry sediment to 1443 mg/kg dry sediment 6 months afterwards. In the same period, *Aphelochaeta marioni* increased in abundance to a mean of 76 individuals/m^2, which placed it among the top five dominant species in the faunal assemblage. It was suggested that the population explosion occurred due to the increased food availability because of accumulation of organic matter resulting from high mortality of browsers. Six years later, abundance of *Aphelochaeta marioni* began to fall away again, accompanied by gradual decontamination of the sediments.

Tubificoides benedii was found in UK waters near oil refineries as the sole surviving member of the macrofauna. Populations were, however, apparently reduced and the worms were absent from areas of oil discharge and other studies indicate sensitivity to oiling (Giere & Pfannkuche, 1982).

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) 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 evidence directly relating to the effects of synthetic chemicals on *Aphelochaeta marioni*. Waldock *et al.* (1999) reported that the species diversity of polychaete infauna, including *Aphelochaeta marioni*, in the Crouch Estuary increased in the three years after the use of TBT was banned within the estuary, suggesting that TBT had suppressed their abundance previously. Furthermore, Beaumont *et al.* (1989) concluded that TBT had a detrimental effect on the larval and/or juvenile stages of infaunal polychaetes.

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.

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

Connor *et al.* (1997a) described sediments in which *Aphelochaeta marioni* is commonly found as usually with a "black anoxic layer close to the sediment surface." Broom *et al.* (1991) recorded that *Aphelochaeta marioni* (studied as *Tharyx marioni*) characterized the faunal assemblage of very poorly oxygenated mud in the Severn Estuary. They found *Aphelochaeta marioni* to be dominant where the redox potential at 4 cm sediment depth was 56 mV and, therefore, concluded that the species was tolerant of very low oxygen tensions. It is likely that feeding, growth and reproduction would be impaired under sustained low oxygen conditions.

Oligochaetes, such as *Tubificoides* spp. vary in their tolerance of hypoxia and associated high sulphide levels. Most enchytraaids and naidids are sensitive to hydrogen sulphide and hypoxia while tubificids are often more resistant (Giere, 2006). *Tubificoides benedii* has a high capacity to tolerate anoxic conditions, its extreme oxygen tolerance is based on an unusually low respiration rate (Giere *et al.*, 1999). Respiration rates of *Tubificoides benedii* measured at various oxygen concentrations showed that aerobic respiration is maintained even at very low oxygen concentrations (Giere *et al.*, 1999). Birtwell & Arthur (1980) showed that *Tubificoides benedii* could tolerate anoxia in the Thames Estuary (LT_{50} = 58.8 hours at 20°C, 26.6 hours at 25°C and 17.8 hours at 30°C in experiments with worms acclimated to 20°C.)

Nephtys hombergii inhabits intertidal areas where resistance to low oxygen is needed and sulphide levels can reach up to 1 mM (Giere, 1992; Thierman *et al.*, 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 utilizing 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 5 days (Schöttler, 1982) and do not switch from aerobic to anerobic metabolic pathways until oxygen saturation decreases <12% (Schöttler, 1982).

Sensitivity assessment. The characterizing species are likely to only be affected by severe deoxygenation episodes. Resistance to deoxygenation at the pressure benchmark level is likely to be **High.** Resilience of the biotopes is likely to also be **High** and the biotopes are therefore considered **Not Sensitive** 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

This pressure relates to increased levels of nitrogen, phosphorus and silicon in the marine environment compared to background concentrations. The benchmark is set at compliance with WFD criteria for good status, based on nitrogen concentration (UKTAG, 2014). The biotopes are, therefore, considered **Not Sensitive** at the pressure benchmark that assumes compliance with good status as defined by the WFD.

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

Kędra *et al.* (2010) reported *Aphelochaeta mariori* that occurred in the Hornsundfjord, Svalbard, where primary production has been recorded as 120 gC/m^2/yr. Covazzi Harriague *et al.* (2007) reported *Aphelochaeta mariori* at sites with organic matter sedimentation as high as 359 mg/m^2/hr in the Ligurian Sea, Italy. Furthermore, Markert *et al.* (2010) compared macrofaunal communities in the Wadden Sea in reefs dominated by *Mytilus edulis* and *Cassostrea gigas* and found *Aphelochaeta mariori* as a dominate species throughout the study site, which suggested the species was unlikely to be affected by organic enrichment.

Tubificoides benedii is very tolerant of high levels of organic enrichment and often dominate sediments where sewage has been discharged or other forms of organic enrichment have occurred (Pearson & Rosenberg, 1978; Gray, 1971; McLusky *et al*., 1980). Their tolerance for organic enrichment is attributed to their adaptation to live in and feed on enriched organic deposits (Pearson & Rosenberg, 1978), and their high population densities in such areas is enhanced by the lack of predation and competition. *Tubificoides benedii* are abundant in mussel beds (mussel relaying may be the source of smothering) which has been attributed to their tolerance of organically rich deoxygenated sediment (Commito & Boncavage, 1989). *Tubificoides benedii* has also been found in elevated abundances in areas of organic enrichment around fish farms (Haskoning, 2006).

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.*, 1998), suggesting the species is likely to be resistant to some organic enrichment.

Sensitivity assessment. The evidence presented suggest the characterizing species may not be affected by organic enrichment at the benchmark level. Resistance and resilience are therefore assessed as **High** and the biotopes are considered **Not Sensitive** to organic enrichment (deposit of 100 gC/m^2/yr).

Physical Pressures

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

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

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

If the cohesive mud and sandy mud that characterize these biotopes were replaced with rock substrata, this would represent a fundamental change to the physical character of the biotopes. The characterizing species would no longer be supported and the biotopes would be lost and/or reclassified.

Sensitivity assessment. Resistance to the pressure is considered **None** and resilience **Very Low**. 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

Aphelochaeta marioni has been recorded from a variety of different sediment types. In the intertidal area of the Wadden Sea, it achieved highest abundance where the sediment fraction smaller than 0.04 mm diameter was greater than 10% of the total sediment (Farke, 1979). *Tubificoides benedii* (studied as *Peloscolex benedeni*) is found in a range of substratum types from sandy mixed habitats, fine sands and coarse sands (Giere & Pfannkuche, 1982). High densities of *Nephtys hombergii* were found in substrata of 0.3% particles >0.25 mm and 5.8% <0.125 mm in diameter, but the worm tolerated up to 3.8% 0.25 mm and 2.2-15.9% <0.125 mm (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. Degraer *et al.* (2006) summarized that the higher the medium grain size of the sediment, the lower the relative occurrence of *Nephtys hombergii* and in grain sizes over 0.5 mm the species was absent in the Belgium part of the North Sea.

Sensitivity assessment. The characterizing species of these biotopes occur in a range of substrata and are likely to resist a change in sediment type by 1 Folk class from, for example, sandy mud to muddy sand (based on the Long, 2006 simplification). However, this would probably represent a fundamental change in the character of the biotopes, and a change in the abundance of the characteristic species, resulting in the loss and/or reclassification of the biotopes. Resistance is therefore assessed as **None** and resilience as **Very Low** given the permanent nature of the pressure and the biotopes are considered to have **High** sensitivity to a change in seabed type by one Folk class.

Habitat structure changes - removal of substratum (extraction)	None Q: Low A: NR C: NR	Medium Q: High A: Low C: Medium	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, and will expose underlying sediment which may be anoxic and/or of a different character or bedrock 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 conditions to which they are not suited. Removal of 30 cm of surface sediment will remove the infaunal community and other species present in the biotopes. For instance, *Aphelochaeta marioni* lives buried in soft sediments with the majority of individuals found in the upper 4 cm of the sediment (Rayment, 2007a). Removal of the substratum to 30 cm would result in the loss of the characterizing species. 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. Hydrodynamics and sedimentology (mobility and supply) influence the recovery of soft sediment habitats (Van Hoey *et al*., 2008).

Sensitivity assessment. Extraction of 30 cm of sediment will remove the characterizing biological component of the biotopes. Resistance of the biotopes is assessed as **None**. Resilience of SS.SMu.SMuVS.AphTubi is likely to be **Medium** given the low energy environment where the biotope occurs, whereas resilience of SS.SMu.SMuVS.NhomTubi is likely to be **High**. Both biotopes sensitivity are therefore assessed as **Medium**.

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

Aphelochaeta marioni is a soft bodied organism which exposes its palps and cirri at the surface while feeding (Rayment, 2007a). The species lives infaunally in soft sediment, usually within a few centimetres of the sediment surface. Physical disturbance, such as dredging or dragging an anchor, would be likely to penetrate the upper few centimetres of the sediment and cause physical damage to *Aphelochaeta marioni*. De Biasi & Pacciardi (2008) compared macrobenthic communities in a commercial fishing ground exploited by otter trawling with an area closed to fishing for over 10 years in the Adriatic Sea. The authors found that polychaetes, including *Aphelochaeta* spp. were among the species dominating the disturbed areas, which is likely to result from the ability of the species to recolonize disturbed areas rapidly, rather than indicate that the polychaetes are resistant to disturbance of the seabed surface.

Tubificoides benedii can be relatively deeply buried and could avoid direct exposure to abrasion although sediment disturbance and compaction could damage these soft-bodied species, and oligochaetes in general are not found in high abundances in sediments with high levels of disturbance from wave action. Experimental studies on crab-tiling impacts have found that densities of *Tubificoides benedii* and *Tubificoides pseudogaster* were higher in non-trampled plots (Sheehan *et al*., 2010), indicating that these oligochaetes have some sensitivity to trampling. Whomersley *et al*. (2010) conducted experimental raking on intertidal mudflats at two sites (Creeksea Crouch Estuary England, and Blackness lower Forth Estuary, Scotland), where *Tubificoides benedii* were dominant species. For each treatment, 1 m^2 plots were raked twice to a depth of 4 cm (using a garden rake). Plots were subject to either low intensity treatments (raking every four weeks) or high (raking every two weeks). The experiment was carried out for 10 months at Creeksea and a year at Blackness. The high and low raking treatments appeared to have little effect on *Tubificoides benedii* (Whomersley *et al*., 2010).

Collie *et al*. (2000) found that *Nephtys hombergii* displayed a negative effect on abundance 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. The biotopes will be impacted if damage to seabed surface features is widespread, however, motile and opportunistic fauna, such as *Tubificoides benedii* may recover quickly. *Nephtys hombergii* shows a greater negative impact (Collie *et al*., 2000; Ferns *et al*., 2000). Resistance is assessed as **Low** and resilience is assessed as **High**, providing a sensitivity assessment of **Low.**

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

Activities that penetrate below the surface would remove a significant proportion of the characterizing species within the direct area of impact (see evidence under ‘abrasion’ above). Resistance of the biotopes is therefore assessed as **Low**, although the significance of the impact for the bed will depend on the spatial scale of the pressure footprint. Resilience is assessed as **High**, and sensitivity is assessed as **Low**.

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

The biotopes are 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. *Aphelochaeta marioni* lives infaunally and is a surface deposit feeder (Rayment, 2007a), therefore relying on a supply of nutrients at the sediment surface. An increased rate of siltation may result in an increase in food availability and therefore growth and reproduction of *Aphelochaeta marioni*. However, food availability would only increase if the additional suspended sediment contained a significant proportion of organic matter and the population would only be enhanced if food was previously limiting. A decrease in the suspended sediment would result in a decreased rate of deposition on the substratum surface and therefore a reduction in food availability for *Aphelochaeta marioni*. This would be likely to impair growth and reproduction.

Tubificoides benedii displays preference for fine organic enriched sediments and may, therefore, increase in abundance if suspended solids settle and lead to increased organic enrichment (Gogina *et al*., 2010).

Sensitivity assessment. Changes in light penetration or attenuation associated with this pressure are not relevant to *Nephtys hombergii*, *Aphelochaeta marioni* and *Tubificoides benedii*. 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 these characterizing species. The following sensitivity assessment relies on expert judgement, utilizing evidence of species traits and distribution and therefore confidence has been assessed as low. Resistance is **High** as no significant negative effects are identified and potential benefits from increased food resources may occur. Resilience is also **High** as no recovery is required under the likely impacts. Sensitivity of the biotopes is therefore assessed as **Not Sensitive.**

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

Aphelochaeta marioni lives infaunally in soft sediments and moves by burrowing. It deposit feeds at the surface by extending contractile palps from its burrow. An additional 5 cm layer of sediment would result in a temporary cessation of feeding activity, and therefore growth and reproduction are likely to be compromised. However, *Aphelochaeta marioni* would be expected to quickly relocate to its favoured depth, with no mortality. Kędra *et al.* (2010) reported *Aphelochaeta mariori* to occur in the Hornsundfjord, Svalbard, where sedimentation rates can vary between 0.1-35 cm/yr.

Tubificoides live relatively deeply buried and can tolerate periods of low oxygen that may occur following the deposition of a fine layer of sediment. In addition, the presence of this species in areas experiencing deposition, such as estuaries, indicate that this species is likely to have a high tolerance to siltation events. *Tubificoides* spp. showed some recovery through vertical migration following the placement of a sediment overburden 6 cm thick on top of sediments (Bolam, 2011). Whomersley *et al*. (2010) experimentally buried plots on intertidal mudflats at two sites (Creeksea Crouch Estuary, England, and Blackness lower Forth Estuary, Scotland), where *Tubificoides benedii* were dominant species. For each treatment, anoxic mud was spread evenly to a depth of 4 cm on top of each treatment plot. The mud was taken from areas adjacent to the plots, and was obtained by scraping off the surface oxic layer and digging up the underlying mud from approximately 20 cm depth. Plots were subject to either low intensity treatments (burial every four weeks) or high (burial every two weeks). The experiment was carried out for 10 months at Creeksea and a year at Blackness. At Creeksea numbers of *Tubificoides benedii* increased in both burial treatments until the third month (high burial) and sixth month (low burial). At Blackness, increased numbers of *Tubificoides benedii* were found in both burial treatments after one month (Whomersley *et al*., 2010).

In the low energy environment where the biotopes occur, a ‘light’ deposition of sediments is likely to be cleared in a few tidal cycles.

Sensitivity assessment. The characterizing species *Nephtys hombergii*, *Aphelochaeta marioni* and *Tubificoides benedii* live in the sediment, to depths to 15 cm and are considered likely to resist smothering by 5 cm of sediment. Resistance and resilience are, therefore, assessed as **High** and the biotopes are considered **Not Sensitive** to a ‘light’ deposition of up to 5 cm of fine material in a single discrete event.

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

Aphelochaeta marioni lives infaunally in soft sediments and moves by burrowing. It deposit feeds at the surface by extending contractile palps from its burrow. An additional layer of sediment would result in a temporary cessation of feeding activity, and therefore growth and reproduction are likely to be compromised. However, *Aphelochaeta marioni* would be expected to quickly relocate to its favoured depth, with no mortality. Kędra *et al.* (2010) reported *Aphelochaeta mariori* to occur in the Hornsundfjord, Svalbard, where sedimentation rates can vary between 0.1-35 cm/yr. Furthermore, Do *et al.* (2012) studied the macrobenthos recovery in the Arcachon Bay (France) following a deposition of sediment up to 10 cm thick that resulted from dredging activities. The authors reported *Aphelochaeta marioni* as considerably reduced or absent from impacted areas characterized mainly by mud substrata.

The pressure benchmark (30 cm deposit) represents a significant burial event and the deposit may remain for some time in a sheltered mudflat. 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.

Sensitivity assessment. Resistance is assessed as **Low** and resilience as **High** and the biotopes are considered to have **Low** 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

None of the species in the biotopes are likely to be sensitive to noise or vibration at the benchmark level and no information was found concerning the intolerance to noise. Species within the biotopes can probably detect vibrations caused by noise and in response may retreat in to the sediment for protection. However, the characterizing species are unlikely to be affected by noise pollution and so the biotopes are assessed as **Not Sensitive**.

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

Changes in light availability impact primary production by phytoplankton in the water column and by the microphytobenthos on the sediment surface, which in turn may affect food availability for the characterizing species. Farke (1979) noted that *Aphelochaeta marioni* is intolerant to visual disturbance in a microsystem in the laboratory possibly due to its nocturnal life habits (Farke, 1979). In order to observe feeding and breeding in the microsystem, the animals had to be gradually acclimated to lamp light. Even then, additional disturbance, such as an electronic flash, caused the retraction of palps and cirri and cessation of all activity for some minutes. Visual disturbance, in the form of direct illumination during the species' active period at night, may therefore result in loss of feeding opportunities, which may compromise growth and reproduction.

Sensitivity assessment. However, the characterizing community of the biotopes live infaunally and are unlikely to be directly dependent on sunlight so the biotopes are considered to have **High** resistance and, by default, **High** resilience and therefore is **Not Sensitive** to the introduction of light or shading.

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	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: NR C: NR

Most species will respond to the shading caused by the approach of a predator, however, their visual acuity is probably very low. Farke (1979) noted that *Aphelochaeta marioni* was intolerant to visual disturbance in a microsystem in the laboratory possibly due to its nocturnal life habits (Farke, 1979). In order to observe feeding and breeding in the microsystem, the animals had to be gradually acclimated to lamp light. Even then, additional disturbance, such as an electronic flash, caused the retraction of palps and cirri and cessation of all activity for some minutes. Most aquatic oligochaetes, such as *Tubificoides* spp. have no eyes, although a few have simple ocelli (eyspots) which are light receptors. However, as the characterizing species live in the sediment, the species will most probably not be impacted at the pressure benchmark.

Sensitivity assessment. At the pressure benchmark, resistance is assessed as **High** and resilience as **High** and the biotopes are assessed as '**Not sensitive**'.

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 biotopes are not cultivated or likely to be translocated. This pressure is therefore considered **Not Relevant**.

	Resistance	Resilience	Sensitivity
Introduction or spread of invasive non-indigenous species	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

The biotopes may be exposed to a number of invasive species that can cause impacts. The largest effect may be from species that significantly alter the character of the biotopes, such as reef-forming species and invasive vegetation. Commito (1987) found that the population density of *Tubificoides benedii* was the same or higher in mussel beds than in open areas, suggesting that colonization of sediments by the Pacific oyster *Magallana gigas* would not necessarily impact the population (although it would alter the character of the biotopes). Tang & Kristensen (2010) found that abundance of macrofauna, including *Tubificoides*, was lower in marsh invaded by the hybrid cordgrass *Spartina anglica* than in mudflats. Colonization of upper mudflats by this species would alter the character of the biotopes resulting in loss and reclassification.

Sensitivity assessment. The biotopes may be sensitive to invasion by *Spartina anglica* which would alter the character of the mudflat and the biological assemblage. Resistance is assessed as **None** and resilience as **Very Low** as the biotopes will not recover unless the INIS is removed. Sensitivity is therefore assessed as **High**.

	Resistance	Resilience	Sensitivity
Introduction of microbial pathogens	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: NR C: NR

Introduced organisms (especially parasites or pathogens) are a potential threat in all coastal ecosystems. Little information was found regarding microbial infection of polychaetes, although Gibbs (1971) recorded that nearly all of the population of *Aphelochaeta marioni* in Stonehouse Pool, Plymouth Sound, was infected with a sporozoan parasite belonging to the acephaline gregarine genus *Gonospora*, which inhabits the coelom of the host. No evidence was found to suggest that gametogenesis was affected by *Gonospora* infection and there was no apparent reduction in fecundity.

Marine oligochaetes host numerous protozoan parasites without apparent pathogenic effects even at high infestation levels (Giere & Pfannkuche, 1982).

Sensitivity assessment. The biotopes are judged to have **High** resistance to this pressure. By default, resilience is assessed as **High** and the biotopes are classed as **Not Sensitive**.

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

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 repopulation would initially occur 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).

Sensitivity assessment. Resistance is **Low** for SS.SMu.SMuVS.NhomTubi due to direct removal of a characterizing species *Nephtys hombergii*, that on commercial scales can remove a large proportion of the population. For instance, Neves de Carvalho *et al.* (2013) calculated that bait digging activities in the Douro estuary, Portugal may remove up to 9.9 tonnes of *Hediste diversicolor*. Resilience is assessed as **Medium**, as regions that are not regularly harvested may recover rapidly but continued harvesting will impact the population. Sensitivity of SS.SMu.SMuVS.NhomTubi is assessed as **Medium**. 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 would cause longer term impacts.

On the other hand, it is extremely unlikely that species indicative of sensitivity of SS.SMu.SMuVS.AphTubi would be targeted for extraction, so this pressure is therefore considered **Not Relevant** for SS.SMu.SMuVS.AphTubi.

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

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 the 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). Hall & Harding (1997) demonstrated that commercial cockle harvesting by suction dredging had significant effects on soft-sediment infaunal communities. Following dredging, species numbers were reduced by up to 30% and abundances by up to 50%.

Collie *et al.* (2000) identified that well established intertidal communities suffered the greatest impact from bottom towed fishing activities. The review concluded that there were ecologically important impacts from removal of >50% of fauna from bottom towed fishing activity (dredge and trawls) (Collie *et al.*, 2000). However, the burrowing and tunnelling traits of the characterizing species may provide some resistance to this pressure. Kaiser *et al.* (2001) carried out experimental hand raking, similar to that used in intertidal cockle fisheries. Both small and large raked plots showed changed communities in comparison to control plots, smaller plots recovered in 56 days, whilst larger plots remained in an altered state.

Collie *et al.* (2000) found that *Nephtys hombergii* abundance was negatively affected by fishing activities. Mean response of infauna and epifauna communities to fishing activities was also 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).

Aphelochaeta marioni is a soft bodied organism which exposes its palps and cirri at the surface while feeding (Rayment, 2007a). The species lives infaunally in soft sediment, usually within a few centimetres of the sediment surface. Physical disturbance, such as dredging or dragging an anchor, would be likely to penetrate the upper few centimetres of the sediment and cause physical damage to *Aphelochaeta marioni*.

Sensitivity assessment. Resistance is **Low** due to direct removal or damage of characterizing species that on commercial scales can remove a large proportion of the population. Resilience is assessed as **Medium** as regions that are not regularly harvested may recover rapidly but continued harvesting will impact the population. Sensitivity is assessed as **Medium**. It is important to consider that the spatial extent and duration of areas impacted by fishing gear effort is important to consider when assessing this pressure as smaller scale extraction may not impact the entire extent of the biotopes but greater scale extraction over a long period would cause longer term impacts. The type of fishing activity is also important to consider in relation to the type and severity of the impact.

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