MarLIN

Marine Information Network

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

Nephtys hombergii and *Streblospio shrubsolii* in littoral mud

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

Matthew Ashley

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Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [https://www.marlin.ac.uk/habitats/detail/1100]. All terms and the MarESA methodology are outlined on the website (https://www.marlin.ac.uk)

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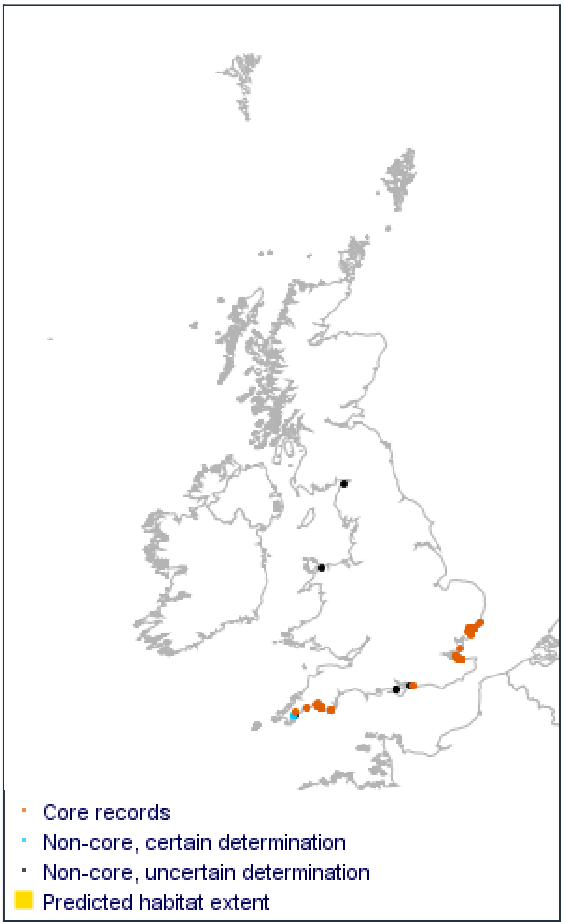

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Matthew Ashley **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A2.321	*Nephtys hombergii* and *Streblospio shrubsolii* in littoral mud
JNCC 2015	LS.LMu.UEst.NhomStr	*Nephtys hombergii* and *Streblospio shrubsolii* in littoral mud
JNCC 2004	LS.LMu.UEst.NhomStr	*Nephtys hombergii* and *Streblospio shrubsolii* in littoral mud
1997 Biotope		

Description

Soft wet mud with a fine sand fraction, on the mid and lower shore of sheltered estuaries, usually with an anoxic layer present within the first 5 cm of the sediment. The infauna is relatively poor, dominated by the polychaetes *Nephtys hombergii*, *Streblospio shrubsolii*, and *Aphelochaeta marioni*. The oligochaete *Tubificoides benedii* is also characterizing for this biotope, and *Hediste diversicolor* may be common. (Information from Connor *et al.*, 2004; 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

The biotope as occurring in soft wet mud with a fine sand fraction, on the mid and lower shore of sheltered estuaries, usually with an anoxic layer present within the first 5 cm of the sediment (Connor *et al.* 2004). The infauna is relatively poor, dominated by the polychaetes *Nephtys hombergii*, *Streblospio shrubsolii*, and *Aphelochaeta marioni*. The oligochaete *Tubificoides benedii* is also characterizing for this biotope, and *Hediste diversicolor* may be common.

In this assessment the important characterizing species *Nephtys hombergii*, *Streblospio shrubsolii*, and *Aphelochaeta marioni* are considered in detail, as well as the oligochaete *Tubificoides benedii*. *Hediste diversicolor* contributes to species richness and diversity but is not considered as a important characterizing, defining or structuring species and is not considered within the assessment.

Resilience and recovery rates of habitat

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.

Aphelochaeta marioni is a thin, thread like, segmented worm, typically between 20 and 35 mm in length, although individuals can reach 100 mm in length (Rayment, 2007). 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, 2007). 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). In the laboratory, spawning occurs at night (Farke, 1979). Farke (1979) reported that females rose up into the water column with the tail end remaining in the burrow, and shed their eggs within a few seconds. The eggs sank to form puddles on the sediment. 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 microsystem, 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 the second year of life (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 to 539 (mean=197) and was correlated with the female's number of genital segments, and hence, the female's size and age.

Streblospio shrubsolii and *Tubificoides benedii* are considered opportunistic species and exhibit short lifespans and fast 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).

Resilience assessment. Recovery of the species characterizing the biotope is likely to range from over 1-2 years in the case of *Nephtys hombergii* to months in the case of *Streblospio shrubsolii* and *Tubificoides benedii*. It is important to consider that recovery times and so resilience will depend on presence of suitable habitat, typically higher mud content sediment and the opportunity for larvae to enter a region through larvae transport pathways. Therefore, biotope resilience is assessed as '**High**' (<2 years).

Hydrological Pressures

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

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 evidence was based on Mediterranean 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 were strongly reduced at lower temperatures in winter (Lardicci *et al*., 1997). The timing of growth and reproduction in *Streblospio shrubsolii* depended on the synergistic effects of temperature and photoperiod, so that cues may differ at locations at different latitudes (Chu & Levin, 1989). Both a 5°C increase in temperature for 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), suggesting limited impact from the pressure at benchmark pressures is likely.

Aphelochaeta marioni is distributed over a wide temperature range. It has been recorded from the Mediterranean Sea and Indian Ocean (Hartmann-Schröder, 1974; Rogall, 1977; both cited in Farke, 1979) and 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* 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.

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.

Sensitivity assessment. Typical surface water temperatures around the UK coast vary, seasonally from 4-19°C (Huthnance, 2010). It is likely that the important characteristic 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 Q: High A: Medium C: Medium	High Q: High A: High C: High	Not sensitive 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 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.

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.

Aphelochaeta marioni is distributed over a wide temperature range. It has been recorded from the Western Baltic Sea, South Atlantic Ocean and North Sea (Hartmann-Schröder, 1974; Rogall, 1977: both cited in Farke, 1979) and 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, metabolic activity should quickly return to normal when temperatures increased.

Sensitivity assessment. Typical surface water temperatures around the UK coast vary, seasonally from 4-19°C (Huthnance, 2010). *Aphelochaeta marioni*, *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 assessed as '**Not Sensitive'**.

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

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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Sensitivity assessment. *Nephtys hombergii* are likely to decrease in abundance. 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 is likely to lead to changes 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 LS.LMu.MEst.HedLim (Conner *et al*., 2004).

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

This biotope occurs on the mid and lower shore of sheltered estuaries, with salinities within the MNCR categories of reduced (18-30ppt) to variable (18-35 ppt) (Connor *et al*., 2004). Maximum salinity would be expected to be approximately 18-35□/□□. A decrease of one MNCR salinity category would be to 'Low' 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 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.

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).

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).

Sensitivity assessment *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. *Aphelochaeta marioni*, *Streblospio* *shrubsolii* and *Tubificoides benedii* survive in much lower salinities suggesting resistance and resilience of these species are higher. As decreasing salinity is likely to lead to a change in biotope to one dominated by *Hediste diversicolor* Resistance is assessed as '**Low'** , Resilience is '**High'** given return to reduced or variable salinities and sensitivity is therefore, **'Low'.**

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

The biotope occurs most often in weak or moderately strong tidal streams (Conor *et al*., 2004), suggesting the species characterizing the biotope can adapt to a range of tidal currents, aided by each species burrowing traits.

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*, *Aphelochaeta marioni* 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.

Sensitivity assessment. As 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 the characterizing species, Resistance and Resilience are assessed as '**High'** and the biotope considered '**Not Sensitive**' to a change in water flow at the pressure benchmark level.

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

The biotope and characterizing species occurs 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*, *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, 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*.

Sensitivity Assessment. Some mortality of the characterizing species is likely to occur as a result of emergence regime changes. Resistance is therefore assessed as '**Medium**' and resilience is likely to be '**High**', so the biotope is considered to have '**Low**' sensitivity to emergence regime changes at the pressure benchmark level.

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

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, Alder & McIntyre (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.

Aphelochaeta marioni characteristically inhabits soft sediments in sheltered areas (Broom *et al.*, 1991). 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. Furthermore, individuals may be damaged or dislodged by scouring from sand and gravel mobilized by increased wave action.

Recovery would be influenced by the length of time it would take for the habitat to return to a suitable state for recolonization by adult and juvenile specimens from adjacent habitats, and the establishment of a breeding population. This may take between one and three years, as populations differ in reaching maturity (Dales, 1950; Mettam *et al.*,1982; Olive & Garwood, 1981), from the time that the habitat again becomes suited to the species.

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 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 two main characterizing species *Nephtys hombergii*, *Aphelochaeta marioni*, *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) 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. The following review discusses impacts at higher concentrations than the pressure benchmark.

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.

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 tributyltin (TBT) was banned within the estuary, suggesting that TBT had suppressed their abundance previously.

At concentrations of 1-3 µg/l of TBT there was no significant effects on the abundance of *Hediste diversicolor* or *Cirratulus cirratus* 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.

In general, for estuarine animals, heavy metal toxicity increases as salinity decreases and temperature increases (McLusky *et al*., 1986). As this biotope experiences variable salinity conditions, it is likely that some polychaete species in the biotope 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. The following review discusses impacts at higher concentrations than the pressure benchmark.

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.

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, 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 are often abundant in polluted coastal muds (Giere & Rhode, 1987) and increase in abundance in highly polluted sites compared to sites at a distance from contamination (oil drilling waste) (Gray *et al*., 1990), suggesting this species would actually increase in abundance under this pressure.

Overall, hydrocarbon contamination is likely to adversely affect some members of the community, and more resistant (or opportunistic) species to increase in abundance, resulting in a reduction in species richness.

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. The following review discusses impacts at higher concentrations than the pressure benchmark.

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.

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* or *Cirratulus cirratus* 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) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) 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) 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**.

Some, all be it, limited evidence was retuned 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 Q: High A: Medium C: High	High Q: Medium A: Medium C: Medium	Not sensitive Q: Medium A: Medium C: Medium

Connor *et al.* (1997) 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. Therefore, it was 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.

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

Streblospio shrubsolii is identified as a 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 Q: High A: Medium C: High	High Q: Medium A: Medium C: Medium	Not sensitive Q: Medium A: Medium C: Medium

The biotope is likely to be not sensitive to the pressure at the benchmark levels, however evidence was available on responses to further 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.*, 1998). 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, 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, UK during periods of gross pollution in 1971-1973 (Gray, 1976).

Raman & Ganapati (1983) studied the distribution of *Aphelochaeta marioni* (studied as *Tharyx marioni*) in relation to a sewage outfall in Visakhaptnam Harbour, Bay of Bengal. Increased nutrients often derive from sewage inputs and presence of species such as *Aphelochaeta marioni* in such situations (for instance Broom *et al.*, 1991) may reflect tolerance to high nutrients or to deoxygenated conditions or both. *Aphelochaeta marioni* was found to be dominant in the 'semi-healthy zone' characterized by low nutrients (nitrate 0.02 mg/l, phosphate 0.88 mg/l). *Aphelochaeta marioni* was not found in high numbers in the polluted zone close to the sewage outfall, characterized by high nutrients (nitrate 0.042-0.105 mg/l, phosphate 2.35-3.76 mg/l) (Rayment, 2007). This would suggest that *Aphelochaeta marioni* is intolerant of eutrophication. However, it would be expected that an increase in organic nutrients would lead to increased food availability for the deposit feeding *Aphelochaeta marioni*. Furthermore, Dauvin (1982, 2000) recorded an increase in abundance of *Aphelochaeta marioni* following an oil spill which resulted in an explosion of plant growth due to high mortality of grazers. Therefore, the available evidence on the resistance of *Aphelochaeta marioni* to nutrient changes does not allow consistent conclusions to be drawn.

Sensitivity assessment. The characterizing species show '**High'** Resistance to increased pollution and turbidity, Resilience is therefore also '**High'**, and the biotope is characterized as **'Not sensitive'**.

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

Kędra *et al.* (2010) reported *Aphelochaeta mariori* to occur in the Hornsundfjord, Svalbard, where primary production has been recorded as 120 gC/m2/yr. Covazzi-Harriague *et al.* (2007) reported *Aphelochaeta mariori* at sites with organic matter sedimentation as high as 359 mg/m2/h 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, suggesting the species is unlikely to be affected by enhanced 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 evidence from direct studies was available, confidence in this assessment is '**High'**, due to the incontrovertible nature of this pressure.

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

This biotope is only found in sediment, in particular sandy mud or mud and the burrowing organisms, *Nephtys hombergii*, *Aphelochaeta marioni*, *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. 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 sediment type)	None	Very Low	High
	Q: High A: High C: Medium	Q: High A: High C: High	Q: High A: High C: Medium

The biotope occurs in littoral mud (JNCC, 2015). A change in 1 Folk class (based on UK SeaMap simplified classification) would result in a change to mixed, sandy or coarse sediments. The characterizing species may colonize a variety of substrata, providing some resistance to an increase in mud or gravel content. However, changes in gravel content may lead to decreased abundance of characterizing species and increased abundance of competing species.

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).

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) summarized 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.

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.

Sensitivity assessment. Although the characterizing species are mobile and likely to move to occupy more suitable sediment, the biotope will be affected by a change from soft wet mud with a fine sand fraction if an increased in gravel content occurs, as characterizing species will reduce in abundance. The loss of the littoral mud that characterizes this habitat would change the character of the biotope and is likely to lead to reclassification. For example, a change to sands would likely result in the biotope reverting to a littoral sand biotope. Based on a change in character, the biotope is considered to have 'No' resistance to this pressure, resilience is assessed as Very 'Low' as a change at the pressure benchmark is permanent and biotope sensitivity is assessed as 'High'.

	Resistance	Resilience	Sensitivity
Habitat structure changes - removal of substratum (extraction)	None Q: High A: High C: High	High Q: High A: High C: High	Medium Q: High A: High C: High

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 30 cm. The process of extraction is considered to remove all biological components of the biotope group and the sedimentary habitat although similar sediments may remain. For instance, *Aphelochaeta marioni* lives buried in soft sediments with the majority of individuals found in the upper 4 cm of the sediment (Rayment, 2007). Removal of the substratum to 30 cm would result in the loss of the characterizing species.

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

	Resistance	Resilience	Sensitivity
Abrasion/disturbance of the surface of the substratum or seabed	Medium Q: High A: Medium C: Medium	Low Q: High A: Medium C: Medium	Low 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'.

	Resistance	Resilience	Sensitivity
Penetration or disturbance of the substratum subsurface	Low Q: High A: High C: High	High Q: High A: High C: High	Low Q: High A: High C: High

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

Aphelochaeta marioni lives infaunally and is a surface deposit feeder (Rayment, 2007), 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*, *Streblospio shrubsolii* 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, utilising 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 biotope is therefore assessed as '**Not Sensitive'.**

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

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. The characterizing species *Nephtys hombergii* , *Aphelochaeta marioni* , *Streblospio shrubsolii* and *Tubificoides benedii* live in the sediment, to depths to 15cm and would be expected to be well adapted to these conditions.

Longer term deposition of fine material (e.g. continuous deposition) would be expected to lead to higher densities of macrobenthic organisms. For example, in the North Sea (Belgium) deposition of fine particle sediment, disturbed by scour around the base of a wind farm tower led to higher macrobenthic densities and created a shift in macrobenthic communities around the wind farm tower (influenced by the direction fine material had settled) (Coates *et al*., 2014).

Within a Marine Biotic Index compiled by Borja *et al.* (2000) the characterizing species *Nephtys hombergii* is classified within'Group II' which includes species that are indifferent to enrichment, *Streblospio shrubsolii is 'Group III'* which includes species that tolerate disturbance and excess organic content and *Tubificoides benedii* 'Group V' which tolerate high enrichment and polluted conditions. (*Aphelochaeta marioni* was not assessed). 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.

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.

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. These impacts are considered in the 'pollution and other chemical changes' section.

Sensitivity assessment. As the exposure to the pressure is for a single discrete event resistance is assessed as '**High**', 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)	Medium Q: High A: High C: Medium	High Q: High A: Medium C: Medium	Medium Q: High A: Medium C: Medium

Limited evidence was found on responses of characterizing species to a deposition of up to 30 cm of fine material. 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.

Bolam (2011) showed that *Streblospio shrubsolii* vertical migration capability was reduced by deposition of just 6 cm simulated dredged material. *Tubificoides benedii* showed good recovery following deposition of material.

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 marion*i as considerably reduced or absent from impacted areas characterized mainly by mud substrata.

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.

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.

Sensitivity assessment. Deposition of up to 30 cm of fine material is likely to provide different impacts for the different species characterizing the biotope. Behavioural traits suggest the characterizing species are resistant to this pressure as they are mobile within the sediment, although recruitment and survival of juveniles is likely to be impacted. Case studies show *Aphelochaeta marioni* are likely to be considerably reduced and *Tubificoides benedii* are likely to be able to exploit the increased nutrient input and rapidly colonise the deposited sediment. Opportunistic species are likely to colonise the biotope if heavy deposition of fine material occurs. The deposited sediment is likely to release large quantities of organic materials enhancing population density but with the risk that pre-impacted communities will shift to a different state (Coates *et al*., 2014, Coates *et al*., 2015). Resistance is assessed as '**Medium**' as recruitment and survivability of juveniles of characterizing species may be impacted. Resilience is assessed as '**High**' and biotope sensitivity is assessed as **'Low'.**

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

No evidence was returned on the impact of litter on characterizing species for this biotope, although studies show impacts from ingestion of microplastics by subsurface 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 microplastics. For instance, *Arenicola marina* ingests microplastics that are present within the sediment it feeds within. Wright *et al.* (2013) carried out a lab study that displayed presence of microplastics (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. Wright et al. (2013) also present a case study based on their results, that in the intertidal regions of the Wadden Sea, where *Arenicola marina* is an important ecosystem engineer, *Arenicola marina* could ingest 33 m^3 of microplastics a year.

This pressure is **'Not assessed'** as no pressure benchmark has been defined.

Electromagnetic changes	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) 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) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Species within the biotope can probably detect vibrations caused by noise and in response may retreat in to 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 Q: Medium A: Medium C: Medium	High Q: High A: High C: Medium	Not sensitive Q: Medium A: Medium C: Medium

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. 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* 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.

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 mud and sand 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 Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive 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) 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 interaction with bottom towed fishing gears and moorings are addressed under 'surface abrasion'.

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

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 assessed as **'Not relevant'.**

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

Introduction or spread of invasive non-indigenous species	Low Q: High A: High C: Medium	Very Low Q: Low A: NR C: NR	High 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 *Crassostrea giga*s. 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	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR 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.

Sensitivity assessment. Insufficient information was available on introduction of microbial pathogens or metazoan disease vectors to assess this pressure. Although introduced microbial pathogens or metazoan disease vectors needs to be considered an conclusion of **'No Evidence'** is given in the assessment.

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

Sensitivity assessment. Resistance is **'Low'** due to direct removal of a characterizing 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 Q: High A: High C: Medium	High Q: High A: High C: Medium	Low Q: High A: High 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 this biotope, 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).

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 (such as this biotope) 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, 2007). 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 biotope 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.

Bibliography

McLusky D.S., Bryant, V. & Campbell, R., 1986. The effects of temperature and salinity on the toxicity of heavy metals to marine and estuarine invertebrates. *Oceanography and Marine Biology: an Annual Review*, **24**, 481-520.

Adams, T.P., Miller, R.G., Aleynik, D. & Burrows, M.T., 2014. Offshore marine renewable energy devices as stepping stones across biogeographical boundaries. *Journal of Applied Ecology*, **51** (2), 330-338.

Alheit, J., 1978. Distribution of the polychaete genus *Nephtys*: a stratified random sampling survey. *Kieler Meeresforschungen*, **4**, 61-67.

Arndt, C. & Schiedek, D., 1997. *Nephtys hombergii*, a free living predator in marine sediments: energy production under environmental stress. *Marine Biology*, **129**, 643-540.

Attrill, M.J. ed., 1998. *A rehabilitated estuarine ecosystem: The environment and ecology of the Thames estuary*. Berlin: Springer Science & Business Media.

Attrill, M.J. & Rundle, S.D., 2002. Ecotone or ecocline: Ecological boundaries in estuaries. *Estuarine Coastal and Shelf Science*, **55** (6), 929-936.

Barnes, R.S.K., 1994. *The brackish-water fauna of northwestern Europe.* Cambridge: Cambridge University Press.

Beasley, T.M. & Fowler, S.W., 1976. Plutonium and Americium: uptake from contaminated sediments by the polychaete *Nereis diversicolor*. *Marine Biology*, **38**, 95-100.

Bentley, M.G., Olive, P.J.W., Garwood, P.R. & Wright, N.H., 1984. The spawning and spawning mechanism of *Nephtys caeca* (Fabricius, 1780) and *Nephtys hombergii* Savigny, 1818 (Annelida: Polychaeta). *Sarsia*, **69**, 63-68.

Beukema, J.J., 2002. Expected changes in the benthic fauna of Wadden Sea tidal flats as a result of sea-level rise or bottom subsidence. *Journal of Sea Research*, **47** (1), 25-39.

Bolam, S.G., 2011. Burial survival of benthic macrofauna following deposition of simulated dredged material. *Environmental Monitoring and Assessment*, **181** (1-4), 13-27.

Boon, J.P., Zantvoort, M.B., Govaert, M.J.M.A. & Duinker, J.C ., 1985. Organochlorines in benthic polychaetes (*Nephtys* spp.) and sediments from the southern North Sea. Identification of individual PCB components. *Netherlands Journal of Sea Research*, **19**, 93-109.

Borja, A., Franco, J. & Perez, V., 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. *Marine Pollution Bulletin*, **40** (12), 1100-1114.

Broom, M.J., Davies, J., Hutchings, B. & Halcrow, W., 1991. Environmental assessment of the effects of polluting discharges: stage 1: developing a post-facto baseline. *Estuarine, Coastal and Shelf Science*, **33**, 71-87.

Bryan, G.W. & Gibbs, P.E., 1983. *Heavy metals from the Fal estuary, Cornwall: a study of long-term contamination by mining waste and its effects on estuarine organisms.* Plymouth: Marine Biological Association of the United Kingdom. [Occasional Publication, no. 2.]

Cardell, M.J., Sarda, R. & Romero, J., 1999. Spatial changes in sublittoral soft-bottom polychaete assemblages due to river inputs and sewage discharges. *Acta Oecologica*, **20**, 343-351.

Chu, J.W. & Levin, L.A., 1989. Chu, J.W. & Levin, L.A., 1989. Photoperiod and temperature regulation of growth and reproduction in *Streblospio benedicti* (Polychaeta: Spionidae). *Invertebrate Reproduction & Development*, **15** (2), 131-142.

Clark, R.B. & Haderlie, E.C., 1960. The distribution of *Nephtys cirrosa* and *Nephtys hombergii* of the south western coasts of England and Wales. *Journal of Animal Ecology*, **29**, 117-147.

Clark, R.B., Alder, R.R. & McIntyre, A.D., 1962. The distribution of *Nephtys* sp. on the Scottish coast. *Journal of Animal Ecology*, **31**, 359-372.

Coates, D.A., Deschutter, Y., Vincx, M. & Vanaverbeke, J., 2014. Enrichment and shifts in macrobenthic assemblages in an offshore wind farm area in the Belgian part of the North Sea. *Marine Environmental Research*, **95**, 1-12.

Coates, D.A., van Hoey, G., Colson, L., Vincx, M. & Vanaverbeke, J., 2015. Rapid macrobenthic recovery after dredging activities in an offshore wind farm in the Belgian part of the North Sea. *Hydrobiologia*, **756** (1), 3-18.

Collie, J.S., Hall, S.J., Kaiser, M.J. & Poiner, I.R., 2000. A quantitative analysis of fishing impacts on shelf-sea benthos. *Journal of Animal Ecology*, **69** (5), 785–798.

Collier, L.M. & Pinn, E.H., 1998. An assessment of the acute impact of the sea lice treatment Ivermectin on a benthic community. *Journal of Experimental Marine Biology and Ecology*, **230**, 131-147.

Conde, A., Novais, J.M. & Domínguez, J., 2013. Characterization of an estuarine environment by means of an index based on intertidal macrofauna. *Marine Pollution Bulletin*, **71** (1–2), 129-138.

Connor, D., Allen, J., Golding, N., Howell, K., Lieberknecht, L., Northen, K. & Reker, J., 2004. The Marine Habitat Classification for Britain and Ireland Version 04.05 JNCC, Peterborough. ISBN 1 861 07561 8.

Connor, D.W., Brazier, D.P., Hill, T.O., & Northen, K.O., 1997b. Marine biotope classification for Britain and Ireland. Vol. 1. Littoral biotopes. *Joint Nature Conservation Committee, Peterborough, JNCC Report* no. 229, Version 97.06., *Joint Nature Conservation Committee, Peterborough, JNCC* Report No. 230, Version 97.06.

Cooksey, C. & Hyland, J., 2007. Sediment quality of the Lower St. Johns River, Florida: An integrative assessment of benthic fauna, sediment-associated stressors, and general habitat characteristics. *Marine Pollution Bulletin*, **54** (1), 9-21.

Covazzi-Harriague, A., Misic, C., Petrillo, M. & Albertelli, G., 2007. Stressors affecting the macrobenthic community in Rapallo harbour (Ligurian Sea, Italy). *Scientia Marina*, **71** (4), 705-714.

Da Fonseca-Genevois, V. & Cazaux, C., 1987. *Streblospio benedicti* Webster, 1879 (Annelida, Polychaeta) in the Loire Estuary - biology and ecology. *Cahiers de Biologie Marine*, **28** (2), 231-261.

Dales, R. P., 1950. The reproduction and larval development of *Nereis diversicolor* O. F. Müller. *Journal of the Marine Biological Association of the United Kingdom*, **29**, 321-360.

Dauvin, J.C., 1982. Impact of *Amoco Cadiz* oil spill on the muddy fine sand *Abra alba* - *Melinna palmata* community from the Bay of Morlaix. *Estuarine and Coastal Shelf Science*, **14**, 517-531.

Dauvin, J.C., 2000. The muddy fine sand *Abra alba* - *Melinna palmata* community of the Bay of Morlaix twenty years after the *Amoco Cadiz* oil spill. *Marine Pollution Bulletin*, **40**, 528-536.

De Biasi, A. & Pacciardi, L., 2008. Macrobenthic communities in a fishery exclusion zone and in a trawled area of the middle Adriatic Sea (Italy). *Ciencias Marinas*, **34** (4).

Degraer, S., Wittoeck, J., Appeltans, W., Cooreman, K., Deprez, T., Hillewaert, H., Hostens, K., Mees, J., Berge, V. & Vincx, M., 2006. *The macrobenthos atlas of the Belgian part of the North Sea.* Belgian Science Policy.

Dittmann, S., Günther, C-P. & Schleier, U., 1999. Recolonization of tidal flats after disturbance. In *The Wadden Sea ecosystem: stability, properties and mechanisms* (ed. S. Dittmann), pp.175-192. Berlin: Springer-Verlag.

Do, V.T., de Montaudouin, X., Blanchet, H. & Lavesque, N., 2012. Seagrass burial by dredged sediments: Benthic community alteration, secondary production loss, biotic index reaction and recovery possibility. *Marine Pollution Bulletin*, **64** (11), 2340-2350.

Emery, K.O. & Stevenson, R.E., 1957. *Estuaries and lagoons.* In *Treatise on marine ecology and paleoecology*.1. *Ecology*, (ed. J.W. Hedgpeth), USA: Geological Society of America.

Fallesen, G. & Jørgensen, H.M., 1991. Distribution of *Nephtys hombergii* and *Nephtys ciliata* (Polychaeta: Nephtyidae) in Århus Bay, Denmark, with emphasis on the severe oxygen deficiency. *Ophelia*, Supplement **5**, 443-450.

Farke, H., 1979. Population dynamics, reproduction and early development of *Tharyx marioni* (Polychaeta, Cirratulidae) on tidal flats of the German Bight. *Veroffentlichungen des Instituts fur Meeresforschung in Bremerhaven*, **18**, 69-99.

Ferns, P.N., Rostron, D.M. & Siman, H.Y., 2000. Effects of mechanical cockle harvesting on intertidal communities. *Journal of Applied Ecology*, **37**, 464-474.

Folk, R.L., 1954. The distinction between grain size and mineral composition in sedimentary-rock nomenclature. **62**, *The Journal of Geology*, 344-359.

Germain, P., Miramand, P. & Masson, M., 1984. Experimental study of long-lived radionuclide transfers (americium, plutonium, technetium) between labelled sediments and annelidae (*Nereis diversicolor*, *Arenicola marina*). In *International symposium on the behaviour of long-lived radionuclides in the marine environment*, (ed. A.Cigna & C. Myttenaere), pp. 327-341. Luxembourg: Office for Official Publications of the European Communities.

Gibbs, P.E., 1971. Reproductive cycles in four polychaete species belonging to the family Cirratulidae. *Journal of the Marine Biological Association of the United Kingdom*, **51**, 745-769.

Gibbs, P.E., Langston, W.J., Burt, G.R. & Pascoe, P.L., 1983. *Tharyx marioni* (Polychaeta) : a remarkable accumulator of arsenic. *Journal of the Marine Biological Association of the United Kingdom*, **63**, 313-325.

Giere, O., 1992. Benthic life in sulfidic zones of the sea-ecological and structural adaptations to a toxic environment. *Verhandlungen der Deutschen Zoologischen Gesellschaft*, **85** (2), 77-93.

Giere, O. & Rhode, B., 1987. Anatomy and ultrastructure of the marine oligochaete *Tubificoides benedii* (Tubificidae), with emphasis on its epidermis-cuticle-complex. In Brinkhurst, R.O. and Diaz, R.J. (eds.). *Aquatic Oligochaeta: Proceedings of the Third International Symposium on Aquatic Oligochaeta* held in Hamburg, Germany September 29-October 4, 1985, Dordrecht: Springer Netherlands, pp. 159-159.

Gill, A.B., Huang, Y., Gloyne-Philips, I., Metcalfe, J., Quayle, V., Spencer, J. & Wearmouth, V., 2009. COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2: EMF-sensitive fish response to EM emissions from sub-sea electricity cables of the type used by the offshore renewable energy industry. *Commissioned by COWRIE Ltd (project reference COWRIE-EMF-1-06)*, **68**.

Gogina, M., Glockzin. M. & Zettler, M.L., 2010. Distribution of benthic macrofaunal communities in the western Baltic Sea with regard to near-bottom environmental parameters. 2. Modelling and prediction. *Journal of Marine Systems*, **80**, 57-70.

Gray, J.S., Clarke, K.R., Warwick, R.M. & Hobbs, G., 1990. Detection of initial effects of pollution on marine benthos - an example from the Ekofisk and Eldfisk oilfields, North Sea. *Marine Ecology Progress Series*, **66** (3), 285-299.

Hiscock, K., 1996. *Marine nature conservation review: rationale and methods.* Joint Nature Conservation Committee.

Hiscock, K., 1983. Water movement. In *Sublittoral ecology. The ecology of shallow sublittoral benthos* (ed. R. Earll & D.G. Erwin), pp. 58-96. Oxford: Clarendon Press.

Huthnance, J., 2010. Ocean Processes Feeder Report. London, *DEFRA on behalf of the United Kingdom Marine Monitoring and Assessment Strategy (UKMMAS) Community*.

JNCC, 2015. The Marine Habitat Classification for Britain and Ireland Version 15.03. (20/05/2015). Available from https://mhc.jncc.gov.uk/

JNCC, 2015. The Marine Habitat Classification for Britain and Ireland Version 15.03. (20/05/2015). Available from https://mhc.jncc.gov.uk/

Kaiser, M., Broad, G. & Hall, S., 2001. Disturbance of intertidal soft-sediment benthic communities by cockle hand raking. *Journal of Sea Research*, **45** (2), 119-130.

Kędra, M., Gromisz, S., Jaskuła, R., Legeżyńska, J., Maciejewska, B., Malec, E., Opanowski, A., Ostrowska, K., Włodarska-Kowalczuk, M. & Węsławski, J., 2010. Soft bottom macrofauna of an All Taxa Biodiversity Site: Hornsund (77 N, Svalbard). *Polish Polar Research*, **31** (4), 309-326.

Lardicci, C., Ceccherelli, G. & Rossi, F., 1997. *Streblospio shrubsolii* (Polychaeta : Spionidae): temporal fluctuations in size and reproductive activity. *Cahiers de Biologie Marine*, **38** (3), 207-214.

Latham, H., Sheehan, E., Foggo, A., Attrill, M., Hoskin, P. & Knowles, H., 2012. *Fal and Helford Recreational Boating Study Chapter 1. Single block, sub-tidal, permanent moorings: Ecological impact on infaunal communities due to direct, physical disturbance from mooring infrastructure*. Falmouth Harbour Commissioners, UK.

Levin, L. & Creed, E., 1986. Effect of temperature and food availability on reproductive responses of *Streblospio benedicti* (Polychaeta: Spionidae) with planktotrophic or lecithotrophic development. *Marine Biology*, **92** (1), 103-113.

Lillicrap, A., Schaanning, M. & Macken, A., 2015. Assessment of the Direct Effects of Biogenic and Petrogenic Activated Carbon on Benthic Organisms. *Environmental Science & Technology*, **49** (6), 3705-3710.

Long, D., 2006. BGS detailed explanation of seabed sediment modified Folk classification. Available from: http://www.emodnet-seabedhabitats.eu/PDF/GMHM3_Detailed_explanation_of_seabed_sediment_classification.pdf

Markert, A., Wehrmann, A. & Kröncke, I., 2010. Recently established *Crassostrea*-reefs versus native *Mytilus*-beds: differences in ecosystem engineering affects the macrofaunal communities (Wadden Sea of Lower Saxony, southern German Bight). *Biological Invasions*, **12** (1), 15-32.

Mathivat-Lallier, M.H. & Cazaux, C., 1991. Life-history of *Nephtys hombergii* in Arcachon Bay. *Estuarine and Coastal Marine Science*, **32**, 1-9.

McLusky, D.S., 1982. The impact of petrochemical effluent on the fauna of an intertidal estuarine mudflat. *Estuarine, Coastal and Shelf Science*, **14**, 489-499.

Mettam, C., Santhanam, V. & Havard, M.C.S., 1982. The oogenic cycle of *Nereis diversicolor* under natural conditions. *Journal of the Marine Biological Association of the United Kingdom*, **62**, 637-645.

Neves de Carvalho, A., Vaz, A.S.L., Sérgio, T.I.B. & Santos, P.J.T.d., 2013. Sustainability of bait fishing harvesting in estuarine ecosystems: Case study in the Local Natural Reserve of Douro Estuary, Portugal estuarinos: Caso de estudo na Reserva Natural Local do Estuário do Douro, Portugal. *Revista de Gestão Costeira Integrada*, **13** (2), 157-168.

Newell, R.C., Seiderer, L.J. & Hitchcock, D.R., 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent biological recovery of biological resources on the sea bed. *Oceanography and Marine Biology: an Annual Review*, **36**, 127-178.

Nilsson, H.C. & Rosenberg, R., 1994. Hypoxic response of two marine benthic communities. *Marine Ecology Progress Series*, **115**, 209-217.

Normandeau, Exponent, T. Tricas, Gill, A., 2011. *Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species 2011*; U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific OCS Region, Camarillo, CA.OCS Study BOEMRE 2011-09.

Olive, P.J.W. & Garwood, P.R., 1981. Gametogenic cycle and population structures of *Nereis (Hediste) diversicolor* and *Nereis (Nereis) pelagica* from North-East England. *Journal of the Marine Biological Association of the United Kingdom*, **61**, 193-213.

Olive, P.J.W., Porter, J.S., Sandeman, N.J., Wright, N.H. & Bentley, M.G. 1997. Variable spawning success of *Nephtys hombergi* (Annelida: Polychaeta) in response to environmental variation. A life history homeostasis? *Journal of Experimental Marine Biology and Ecology*, **215**, 247-268.

Orvain, F., Sauriau, P.-G., Le Hir, P., Guillou, G., Cann, P. & Paillard, M., 2007. Spatio-temporal variations in intertidal mudflat erodability: Marennes-Oléron Bay, western France. *Continental Shelf Research*, **27** (8), 1153-1173.

Oyenekan, J.A., 1986. Population dynamics and secondary production of *Nephtys hombergii* (Polychaeta: Nephtyidae). *Marine Biology*, **93**, 217-223.

Pearson, T.H. & Rosenberg, R., 1978. Macrobenthic succession in relation to organic enrichment and pollution of the marine environment. *Oceanography and Marine Biology: an Annual Review*, **16**, 229-311.

Raman, A.V. & Ganapati, P.N., 1983. Pollution effects on ecobiology of benthic polychaetes in Visakhapatnam Harbour (Bay of Bengal). *Marine Pollution Bulletin*, **14**, 46-52.

Rayment W.J., 2007. *Crepidula fornicata*. Slipper limpet. [online]. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [On-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: <http://www.marlin.ac.uk>

Rodrigues, A.M., Quintino, V., Sampaio, L., Freitas, R. & Neves, R., 2011. Benthic biodiversity patterns in Ria de Aveiro, Western Portugal: Environmental-biological relationships. *Estuarine, Coastal and Shelf Science*, **95** (2–3), 338-348.

Rosenberg, R., 1977. Benthic macrofaunal dynamics, production, and dispersion in an oxygen-deficient estuary of west Sweden. *Journal of Experimental Marine Biology and Ecology*, **26**, 107-33.

Sanders, H.L., 1978. Florida oil spill impact on the Buzzards Bay benthic fauna: West Falmouth. *Journal of the Fisheries Board of Canada*, **35**, 717-730.

Schöttler, U., 1982. An investigation on the anaerobic metabolism of *Nephtys hombergii* (Annelida: Polychaeta). *Marine Biology*, **71** (3), 265-269.

Schueckel, U. & Kroencke, I., 2013. Temporal changes in intertidal macrofauna communities over eight decades: A result of eutrophication and climate change. *Estuarine Coastal and Shelf Science,* **117**, 210-218.

Silva, G., Costa, J.L., De Almeida, P.R. & Costa, M.J., 2006. Structure and dynamics of a benthic invertebrate community in an intertidal area of the Tagus estuary, western Portugal: a six year data series. *Hydrobiologia*, **555**, 115-128.

Suchanek, T.H., 1993. Oil impacts on marine invertebrate populations and communities. *American Zoologist*, **33**, 510-523.

Tait, R.V. & Dipper, R.A., 1998. *Elements of Marine Ecology*. Reed Elsevier.

Thiermann, F., Niemeyer, A-S. & Giere, O., 1996. Variations in the sulfide regime and the distribution of macrofauna in an intertidal flat in the North Sea. *Helgolander Meeresuntersuchungen*, **50**, 87-104.

Vader, W.J.M., 1964. A preliminary investigation in to the reactions of the infauna of the tidal flats to tidal fluctuations in water level. *Netherlands Journal of Sea Research*, **2**, 189-222.

Vandendriessche, S., Derweduwen, J. & Hostens, K., 2015. Equivocal effects of offshore wind farms in Belgium on soft substrate epibenthos and fish assemblages. *Hydrobiologia*, **756** (1), 19-35.

Waldock, R., Rees, H.L., Matthiessen, P. & Pendle, M.A., 1999. Surveys of the benthic infauna of the Crouch Estuary (UK) in relation to TBT contamination. *Journal of the Marine Biological Association of the United Kingdom*, **79**, 225 - 232.

Watson, G.J., Farrell, P., Stanton, S. & Skidmore, L.C., 2007. Effects of bait collection on *Nereis virens* populations and macrofaunal communities in the Solent, UK. *Journal of the Marine Biological Association of the United Kingdom*, **87** (3), 703-716.

Wilson, D.P., 1936. Notes on the early stages of two polychaetes, *Nephtys hombergii* Lamarck and *Pectinaria koreni* Malmgren. *Journal of the Marine Biological Association UK*, **21**, 305-310.

Winter, H., Aarts, G. & Van Keeken, O., 2010. *Residence time and behaviour of sole and cod in the Offshore Wind farm Egmond aan Zee (OWEZ)*. IMARES Wageningen UR.

Wolff, W.J., 1971b. Changes in intertidal benthos communities after an increase in salinity. *Thalassia Jugoslavica*, **7**, 429-434.

Wolff, W.J., 1973. The estuary as a habitat. An analysis of the data in the soft-bottom macrofauna of the estuarine area of the rivers Rhine, Meuse, and Scheldt. *Zoologische Verhandelingen*, **126**, 1-242.

Wright, S.L., Rowe, D., Reid, M.J., Thomas, K.V. & Galloway, T.S., 2015. Bioaccumulation and biological effects of cigarette litter in marine worms. *Scientific reports*, **5**, 14119.

Wright, S.L., Rowe, D., Thompson, R.C. & Galloway, T.S., 2013. Microplastic ingestion decreases energy reserves in marine worms. *Current Biology*, **23** (23), R1031-R1033.