Oligochaetes in littoral mobile sand

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

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2018-03-08

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

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This review can be cited as:
Tillin, H.M. 2018. Oligochaetes in littoral mobile sand. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. DOI https://dx.doi.org/10.17031/marlinhab.1144.1

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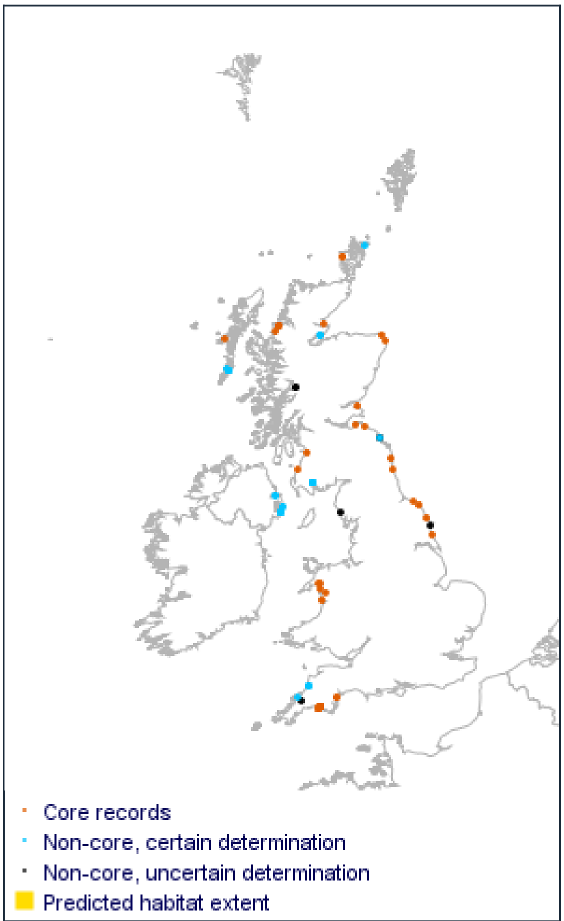

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Dr Heidi Tillin **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A2.222	Oligochaetes in littoral mobile sand
JNCC 2015	LS.LSa.MoSa.Ol	Oligochaetes in littoral mobile sand
JNCC 2004	LS.LSa.MoSa.Ol	Oligochaetes in littoral mobile sand
1997 Biotope		

Description

A species-poor community of oligochaetes occurring in estuarine conditions where sands and gravel are associated with the lower shore river channel in estuaries. The sediment is relatively coarse and mobile due to strong river flow and subject to variable salinity. The biotope also occurs in fully marine conditions on open shores with mobile, medium to fine, usually clean, sand. Oligochaetes, including enchytraeid oligochaetes, constitute the infaunal assemblage. This biotope has been split into two sub-biotopes, based on the physical environment (a full-salinity and a variable salinity type). (Information from Connor *et al.*, 2004; JNCC, 2015).

Depth range

Upper shore, 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 description and characterizing species is taken from (JNCC, 2015). This biotope is defined as a species-poor community of oligochaetes occurring in fully marine or estuarine conditions, within gravels or mobile, medium to fine, usually clean sands. Two sub-biotops are recognised, based on salinity regime, A2.2221- Oligochaetes in full salinity littoral mobile sand and A2.2222- Oligochaetes in variable salinity littoral mobile sand): these both have MarESA sensitivity assessments.

Oligochaetes, including enchytraeid oligochaetes, constitute the infaunal assemblage (these are not recorded to the species level), the sensitivity assessments are thus rather generic and based on Tubificid (largely based on *Tubificoides benedii* as this species is well studied) and Enchytraeid oligochaetes as most marine species belong to these families (Giere & Pfannkuche, 1982). Although the evidence base for assessing sensitivity of oligochaetes is limited compared to other taxa, it is clear that there are species-specific responses to environmental factors and perturbations (Rodriguez & Reynoldson, 2011) and the lack of species information is a key limitation in assessing sensitivity.

Wave exposure, the sedimentary habitat and salinity conditions are key factors structuring this habitat and these factors are considered in the sensitivity assessments where the pressure may alter these.

Resilience and recovery rates of habitat

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

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

Bolam and Whomersley (2003) observed faunal recolonization of fine sediments placed on saltmarsh as a beneficial use and disposal of fine grained dredged sediments. They found that tubificid oligochaetes began colonising sediments from the first week following a beneficial use scheme involving the placement of fine-grained dredged material on a salt marsh in southeast England. The abundance of *Tubificoides benedii* recovered slowly in the recharge stations and required 18 months to match reference sites and those in the recharge stations prior to placement of sediments. The results indicate that some post-juvenile immigration is possible and that an in-situ recovery of abundance is likely to require more than 1 year. Rapid recolonization has also been observed in the tubificid oligochaete *Baltidrilus costata (Tubifex costatus)* appeared in upper sediment layer s in experimentally defaunated patches (4m2) after 3 weeks (Gamenick *et al*., 1996).

Resilience assessment. In general little information was found for *Tubificoides benedii* and other oligochaetes, but, taking into consideration the information above (particularly Bolam & Whomersley, 2003) , this review considers that the recoverability of this species is generally 'High', so that recovery from defaunation is suggested to occur within two years and that therefore, recovery from any impact (resistance is 'None', 'Low' or 'Medium') is assessed as 'High'. This assessment is supported by the biotop dscription (JNCC, 2015), which indicates that this biotop may be lost and then recover on a seasonal basis following increased wave exposre during winter storms.

Hydrological Pressures

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

Deeper burrowing oligochaetes are protected from fluctuations in temperature by the overlaying sediments which dampen changes if poorly drained (Giere & Pfannkuche, 1982). Bamber & Spencer (1984) observed that *Tubificoide*s were dominant species in an area affected by thermal discharge in the River Medway estuary. Sediments were exposed to the passage of a temperature front of approximately 10°C between heated effluent and estuarine waters during the tidal cycles.

Increased temperature was found to trigger the onset of reproduction in *Baltidrilus costata* (studied as *Tubifex costatus*) in the Thames (Birtwell & Arthur, 1980). This effect was non-lethal and may be beneficial to populations.

Sensitivity assessment. The dominance of *Tubificoides* spp. when exposed to a heated effluent suggests that this genus would be highly resistant to an increase in temperature at the pressure benchmark. Biotope resistance is therefore assessed as 'High' and resilience as 'High' (by default), so that the biotope is considered to be 'Not sensitive'.

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

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

Sensitivity assessment. Based on freezing tolerances of *Tubificoides benedii* (Linke, 1939) biotope resistance is assessed as 'High' to decreases in temperature. Resilience is assessed as 'High' (by default) and the biotope is therefore considered to be 'Not sensitive'.

Salinity increase (local)	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: High A: High C: High

Two sub-biotopes of this biotope are recognised based on salinity regine, a full salinity variant (30-35 ppt) and a variable salinity biotope (JNCC, 2015). For the variabl salinity biotope LS.LSa.MoSa.Ol.VS, it is considered that an increase in salinity at the pressure benchmark would result in biotope reclassification to LS.LSa.MoSa.Ol.FS. However, for the full salinity sub-biotope, the assessed change at the pressure benchmark represents a change from full salinity (30-35 ppt) to hypersalinity (>40 ppt). No evidence was found to support an assessment and this pressure is therefore not assessed.

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

The biotope LS.LSa.MoSa.Ol, is present in full and variable salinity habitats (JNCC, 2015), a change at the pressure benchmark therefore represents a change from variable to low (<18 ppt) salinity. Oligochaete dominated biotopes are recorded from a range of salinity regimes from full (LS.LSa.MoSa.Ol; LS.LSa.MoSa.Ol.FS), variable (SS.SMu.SMuVS.CapTubi) reduced (SS.SMu.SMuVS.CapTubi; LS.LMu.UEst.Tben) and low (SS.SMu.SMuVS.LhofTtub) habitats (JNCC,2015). In very low salinities from <15 to 0 ‰ species such as Limnodrilus spp. and Tubifex tubifex are found (Giere & Pfannkuche, 1982). It is therefore considered that a decrease in salinity at the pressure benchmark would result in replacement by oligochaete species more tolerant of lower salinities such as Limnodrilus hoffmeisteri and Tubifex tubifex that characterize the low salinity biotope SS.SMu.SMuVS.LhofTtub. This would result in the loss of the characterizing biotope. Numerous studies suggest that Baltidrilus costata tolerates a wide range of salinities from 1‰ to 28‰ (Giere & Pfannkuche, 1982 and references therein), suggesting that this species is likely to still be present in the biotope.

Sensitivity assessment. A reduction in salinity at the pressure benchmark may lead to species replacement and biotope reclassification to SS.SMu.SMuVS.LhofTtub. Biotope resistance is therefore assessed as 'Low' and resilience as 'High' (following a return to usual habitat conditions), so that biotope sensitivity is assessed as 'Low'.

Sensitivity assessment. A reduction in salinity at the pressure benchmark may lead to species replacement and biotope reclassification to LS.LSa.MoSa.Ol.VS. Biotope resistance is therefore assessed as 'None' and resilience as 'High' (following a return to usual habitat conditions), so that biotope sensitivity is assessed as 'Medium'.

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

This biotope is found in areas subjct to strong river flows (JNCC, 2015). Increases and decreases in water velocity may lead to increased erosion or deposition. The associated pressures alteration to sediment type and siltation are assessed separately.

Experimental increases in near-bed current velocity were achieved over intertidal sandflats by placing flumes on the sediment to accelerate water flows (Zuhlke & Reise, 1994). The increased flow led to the erosion of up to 4cm depth of surface sediments. No significant effect was observed on the abundance of *Capitella capitata* and numbers of *Tubificoides benedii* and *Tubificoides pseudogaster* were unaffected, as they probably avoided suspension by burrowing deeper into sediments. This was demonstrated by the decreased abundance of oligochaetes in the 0-1cm depth layer and increased abundance of oligochaetes deeper in sediments (Zuhlke & Reise, 1994). A single storm event had a similar result with decreased abundance of oligochaetes in surficial layers, coupled with an increase in deeper sediments (Zuhlke & Reise, 1994). Although *Tubificoides* spp. can resist short-term disturbances their absence from sediments exposed to higher levels of disturbance indicate that they would be sensitive to longer-term changes in sediment mobility (Zuhlke & Reise, 1994). Birtwell and Arthur (1980) reported seasonal changes in abundance in *Baltidrilus costata* (as *Tubifex costatus*) which they attributed to erosion of the upper sediment layers caused by high river flows and wave action.

Decreases in water flow with increased siltation of fine particles may alter the physical character of this habitat type as it is already found in sheltered areas. Reductions in waterflow occurring through the presence of trestles (for off-bottom oyster cultivation) arranged in parallel rows in the intertidal area (Goulletquer & Héral, 1997) reducing the strength of tidal currents (Nugues *et al.*, 1996) has been observed to limit the dispersal of pseudofaeces and faeces in the water column and thus increase the natural sedimentation process by several orders of magnitude (Ottman & Sornin, 1985, summarised in Bouchet & Sauriau, 2008). As the characterizing oligochaetes can live relatively deeply buried and in depositional environments with low water flows (based on habitat preferences) and low oxygenation they are considered to be not sensitive to decreases in water flow, however deposition and increases in muds is likely to result in biotope reclassification.

Sensitivity assessment. Where increased or decreased water flows alter the sediment type this could lead to sediment reclassification, this change is assessed in the sedimentary change assessment. An increase at the pressure benchmark may lead to increased erosion of sands and disturb the upper layers. Biotope resistance is assessed as 'Medium' as mobile sands may be present in stronger flows than recorded for this biotope and as particle redistribution may occur during the tidal cycle preventing complete erosion and subsequent loss of the habitat and oligochaetes (JNCC, 2015). Resilience is assessed as 'High' (following restoration of usual conditions) and sensitivity is assessed as 'Low'. The biotope is also considered sensitive to decreased flows (exceeding the pressure benchmark) as deposition of muds may result in biotope reclassification.

Emergence regime changes	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

This biotope is found on the lower shore, mid shore and upper shore (JNCC, 2015). As habitats from the sublittoral to the supralittoral are habitable for tubificds and enchytraeid oligochaetes (Giere, 1993) the biotope is not considered sensitive to changes in emergence that alter emergence periods. The characterizing species are found in subtidal biotopes and a change in tidal regime that led to this biotope becoming permanently submerged would result in biotope reclassification to a biotope such as SS.SMu.SMuVS.OlVS (oligochaetes in variable or reduced salinity infralittoral muddy sediment).

Sensitivity assessment. The biotope based on the biological assemblage is considered to have ‘High’ resistance to changes in emergence and ‘High’ resilience (by default), so that the biotope is considered to be ‘not sensitive to this pressure at the benchmark.

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

This biotope occurs in habitats where estimated wave exposure ranges from exposed to extremely sheltered (JNCC, 2015). Disturbance of sediment by waves may reduce oligochaete abundance (Giere, 1977) and oligochaetes may be absent from very wave exposed shores (Giere & Pfannkuche, 1982 and references therein). As this biotope occurs across a range of wave exposures this is considered to indicate, by proxy, that resistance is ‘High’ and resilience as ‘High’ by default and the biotope is considered to be ‘Not sensitive’.

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.

Contamination at levels exceeding the pressure benchmark may have negative effects. A 2-year microcosm experiment was undertaken to investigate the impact of copper on the benthic fauna of the lower Tyne Estuary (UK) by Hall & Frid (1995). During a 1-year simulated contamination period, 1 mg l−1copper was supplied at 2-weekly 30% water changes, at the end of which the sediment concentrations of copper in contaminated microcosms reached 411 µg g−1. Toxicity effects reduced populations of the four dominant taxa including the oligochaete *Tubificoides* spp.). When copper dosage was ceased and clean water supplied, sediment copper concentrations fell by 50% in less than 4 days, but faunal recovery took up to 1 year, with the pattern varying between taxa. Since the copper leach rate was so rapid it is concluded that after remediation, contaminated sediments show rapid improvements in chemical concentrations, but faunal recovery may be delayed taking up to a year.

Rygg (1985) classified *Tubificoides* spp as highly tolerant species, common at the most copper polluted stations (>200 mg Kg-1) in Norwegian fjords.

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.

In Finland in oligohaline inland waters near an oil refinery, *Baltidrilus costata* (as *Tubifex costatus*) appeared to be sensitive to oil pollution and had completely disappeared from sediments exposed to pollution and did not recolonize during a four year post pollution period (Leppäkoski & Lindström, 1978). *Tubificoides benedii* appears to be more tolerant and was found in UK waters near oil refineries as the sole surviving member of the macrofauna. Populations were however apparently reduced and the worms were absent from areas of oil discharge and other studies indicate sensitivity to oiling (Giere & Pfannkuche, 1982, references therein).

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.

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

No evidence was found for radionuclide uptake by marine oligochaetes.

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

This pressure is **Not assessed**.

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

Oligochaete species vary in their tolerance of hypoxia and associated high sulphide levels. Most enchytraeids and naidids are sensitive to hydrogen sulphide and hypoxia while tubificids are often more resistant (Giere, 2006).

Tubificoides benedii has a high capacity to tolerate anoxic conditions, its extreme oxygen tolerance is based on an unusually low respiration rate (Giere *et al.*, 1999). Respiration rates of *Tubificoides benedii* measured at various oxygen concentrations showed that aerobic respiration is maintained even at very low oxygen concentrations (Giere *et al.*, 1999). Birtwell & Arthur (1980) showed that *Tubificoides benedii* could tolerate anoxia in the Thames Estuary (LT_{50} = 58.8 hours at 20°C, 26.6 hours at 25°C and 17.8 hours at 30°C in experiments with worms acclimated to 20°C.)

Tolerance experiments by Gamenick *et al.* (1996) found that *Baltidrilus costata* (as *Heterochaeta costata)* was not affected by hypoxic conditions for at least 3 days but the addition of sulphide 91.96 mmol/litre) caused mortality after 1 day (Gamenick *et al.*, 1996)

Sensitivity assessments. As this biotope is found in the intertidal oxygen levels will be recharged during the tidal cycle lowering exposure to this pressure for worms that migrate to surface layers. Based on the reported tolerances for anoxia, biotope resistance is assessed as 'High', resilience is assessed as 'High' (by default) and the biotope is considered to be 'Not sensitive'.

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

In nutrient enriched tidal sediments oligochaetes can dominate assemblages (Gray, 1971; Leppäkoski, 1975; Birtwell & Arthur, 1980). Green algae such as *Ulva* spp. may form mats on the surface of the mud during the summer months, particularly if nutrient enrichment occurs.

Sensitivity assessment. As the benchmark is relatively protective and would not lead to blooms of *Ulva* spp. (although green algae may be present on the surface layers of sediments in the summer), biotope resistance is assessed as 'High', resilience is assessed as 'High' and the biotopeis considered to be 'Not sensitive'.

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

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

Sensitivity assessment. Based on the high tolerance of *Tubificoides benedii* for organic enrichment, biotope resistance is assessed as 'High' and resilience as 'High', so that the biotope is considered to be Not sensitive'.

Physical Pressures

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

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

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

A change to an artificial or natural hard substratum would significantly alter the habitat type. The oligochaetes, nemerteans and nematodes that characterize this biotope are infaunal species living within sediment. If the changed habitat contained pockets of sediment these species may still be present but the habitat will be unsuitable overall and the biotope will be reclassified. The presence of hard substratum is likely to support colonization by filamentous green and red algae tolerant of variable salinity.

Sensitivity assessment. Based on the loss of the biotope, resistance is assessed as 'None', recovery is assessed as 'Very low' (as the change at the pressure benchmark is permanent) and sensitivity is assessed as 'High'.

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

This biotope is characterterized by mobile gravels and clean sands (JNCC, 2015). The sediment type present reflects the habitats in which this biotope occurs where wave action removes finer particles. Oligochaete dominated biotopes occur in a range of sedimentary habitats. Although the lack of identification to species level has hampered understanding of species preferences (and the species that typically occur in this biotope) it is clear that at least some species exhibit strong p[references for sediment type. *Tubificoides heterochaetus*for example, sampled in South Carolina salt marsh and tidal inlets was found in significantly greater abundances in coarser sediments where silt and clay fractions were lower (Gillett et al., 2007).

A change in sediment type may therefore lead to species replacement, although an oligochaete dominated biotope may remain.*Tubificoides* benedii (studied as *Peloscolex benedeni*) are found in a range of substratum types from sandy mixed habitats, fine sands and coarse sands (Giere & Pfannkuche, 1982 and references therein). Similarly, *Baltidrilus costata* (as*Tubifex costatus*) is found in mud/silts (Giere & Pfannkuche,1982 and references therein). Giere & Pfannkuche (1982) suggest that factors that correlate to substratum types such as organic matter availability, size and shape of the intertstitial space between grains, the level of sediment disturbance and water content, rather than the sediment type alone are the key factors influencing distribution.

Sensitivity assessment. A change in sediment type is likely to result in biotope reclassification (although a similar infaunal assemblage may be present). Based on the loss of the biotope as classified, resistance is assessed as 'None' and resilience as 'Very Low' (as the change at the pressure benchmark is permanent). Sensitivity is therefore assessed as 'High'.

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

Sedimentary communities are likely to be highly intolerant of substratum removal, which will lead to partial or complete defaunation, expose underlying sediment which may be anoxic and/or of a different character or bedrock and lead to changes in the topography of the area (Dernie *et al*., 2003). Any remaining species, given their new position at the sediment / water interface, may be exposed to conditions to which they are not suited, Removal of 30 cm of surface sediment will remove the oligochaete community and other species present in the biotope. Recovery of the biological assemblage may take place before the original topography is restored, if the exposed, underlying sediments are similar to those that were removed. Hydrodynamics and sedimentology (mobility and supply) influence the recovery of soft sediment habitats (Van Hoey *et al*. 2008).

Sensitivity assessment. Extraction of 30 cm of sediment will remove the characterizing biological component of the biotope. Resistance is assessed as 'None' and biotope resilience is assessed as 'High'. Biotope sensitivity is therefore 'Medium'.

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

OOligochaetes such as Tubificoides benedii can be relatively deeply buried and could avoid direct exposure to abrasion although sediment disturbance and compaction could damage these soft-bodied species and oligochaetes in general are not found in high abundances in sediments with high levels of disturbance from wave action.

Experimental studies on crab-tiling impacts have found that densities of *Tubificoides benedii* and *Tubificoides pseudogaster* were higher in non-trampled plots (Sheehan *et al*. 2010), indicating that these oligochaetes have some sensitivity to trampling. Whomersley *et al*., (2010) conducted experimental raking on intertidal mudflats at two sites (Creeksea- Crouch estuary England and Blackness- lower Forth estuary, Scotland), where *Tubificoides benedii* were dominant species. For each treatment 1 m^2 plots were raked twice to a depth of 4cm (using a garden rake). Plots were subject to either low intensity treatments (raking every four weeks) or high (raking every two weeks). The experiment was carried out for 10 months at Creeksea and a year at Blackness. The high and low raking treatments appeared to have little effect on *Tubificoides benedii* (Whomersley *et al*., 2010)

Sensitivity assessment. The experiments by Whomersley *et al*. (2010), suggest that disturbance of the surficial layers has little effect on *Tubificoides benedii*. Many individuals are likely to be buried more deeply and can migrate to the surface following disturbance, so that little impact is observed through sampling. Abrasion with associated compaction (as in trampling) may have a greater impact. Resistance is therefore assessed as 'medium' and resilience as 'High' (by default) so that sensitivity is assessed as 'Low'.

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

Oligochaetes such as Tubificoides benedii can be relatively deeply buried and could avoid direct exposure to penetration and disturbance of upper sediment layers, although sediment disturbance and compaction could damage these soft-bodied species and oligochaetes in general are not found in high abundances in sediments with high levels of disturbance from wave action.

Whomersley *et al*., (2010) conducted experimental raking on intertidal mudflats at two sites (Creeksea- Crouch estuary England and Blackness- lower Forth estuary, Scotland), where *Tubificoides benedii* were dominant species. For each treatment 1 m^2 plots were raked twice to a depth of 4cm (using a garden rake). Plots were subject to either low intensity treatments (raking every four weeks) or high (raking every two weeks). The experiment was carried out for 10 months at Creeksea and a year at Blackness. The high and low raking treatments appeared to have little effect on *Tubificoides benedii* (Whomersley *et al*., 2010). These results are supported by observations that two experimental passes of an oyster dredge that removed the sediment to a depth of between 15-20 cm did not significantly affect *Tubifcoides benedii* (EMU, 1992).

Sensitivity assessment. The experiments by Whomersley *et al*., (2010) and EMU (1992), suggest that penetration and disturbance of the upper surface has little effect on *Tubificoides benedii*. Many individuals are likely to be buried more deeply and can migrate to the surface following disturbance, so that little impact is observed through sampling. Resistance is therefore assessed as 'Medium' and resilience as 'High' so that sensitivity is assessed as 'Low'.

Changes in suspended solids (water clarity)	Medium Q: Low A: NR C: NR	High Q: High A: Low C: High	Low Q: Low A: Low C: Low

The biological assemblage characterizing this biotope is infaunal and consists of sub-surface deposit feeders. Increased suspended solids are unlikely to have an impact and resistance is assessed as 'High' and resilience as 'High', so that the biotope is considered to be 'not sensitive'. A reduction in suspended solids may reduce deposition and supply of organic matter, resistance to a decrease is therefore assessed as 'Medium' as a shift between deposition and erosion could result in the net loss of surficial sediments. A reduction in organic matter as suspended solids could also reduce production within this biotope. Resistance is assessed as 'Medium' as over a year the impact may be relatively small and resistance is assessed as 'High', following restoration of usual conditions. Biotope sensitivity is therefore assessed as 'Low'.

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

This biotope occurs in areas of mobile sediments and it is likely that the assemblage present undergoes periodic burial as sedimentsshift following increased wave action or water flow. Oligochaete dominated biotopes may occur in sheltered accreting environments such as intertidal mudflats, where deposition rather than erosion is the dominant process, this means that the assemblages present (primarily deposit feeders) are adapted to natural levels of siltation through life history traits and can withstand burial (by repositioning in sediment or similarly extending tubes or feeding and respiration structures above the sediment surface). At low levels of siltation the high bioturbatory nature of mudflat organisms decreases sensitivity to effects (Elliott *et al*. 1998) as sediment turnover rates are relatively rapid. *Tubificoides* live relatively deeply buried and can tolerate periods of low oxygen that may occur following the deposition of a fine layer of sediment. In addition the presence of this species in areas experiencing deposition, such as estuaries, indicate that this species is likely to have a high tolerance to siltation events. *Tubificoides* spp. showed some recovery through vertical migration following the placement of a sediment overburden 6cm thick on top of sediments (Bolam, 2011).

Whomersley *et al*., (2010) experimentally buried plots on intertidal mudflats at two sites (Creeksea- Crouch Estuary, England and Blackness- lower Forth Estuary, Scotland), where *Tubificoides benedii* were dominant species. For each treatment anoxic mud was spread evenly to a depth of 4cm on top of each treatment plot. The mud was taken from areas adjacent to the plots, and was obtained by scraping off the surface oxic layer and digging up the underlying mud from approximately 20cm depth. Plots were subject to either low intensity treatments (burial every four weeks) or high (burial every two weeks). The experiment was carried out for 10 months at Creeksea and a year at Blackness. At Creeksea numbers of *Tubificoides benedii* increased in both burial treatments until the third month (high burial) and sixth month (low burial). At Blackness increased numbers of *Tubificoides benedii* were found in both burial treatments after one month (Whomersley *et al*., 2010).

Sensitivity assessment. The characterizing oligochaetes are considered, based on*Tubificoides benedii*, to be able to survive under a deposit of fine grained sediment up to 5cm thick and to burrow and reposition within this. The assessment is supported by the burial experiments conducted by Whomersley *et al.* (2010). Although fine sediments are cohesive, wave action or water flow within the biotope may remove the deposit mitigating the effects.

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

The pressure benchmark (30 cm deposit) represents a significant burial event and the deposit may be rapifdle removed by water flows and wave action, mitigating effects, or may remain for some time in upper shore examples that are submerged for only short periods. Some impacts on *Tubificoides benedii* and other characterizing oligochaetes may occur and it is considered unlikely that signficiant numbers of the population could reposition, based on (Bolam, 2011). Placement of the deposit will therefore result in a defaunated habitat until the deposit is recolonized. Biotope resistance is therefore assessed as 'Low' as some removal of deposit and vertical migration through the deposit may occur. Resilience is assessed as 'High' as migration and recolonization of oligochaetes is likely to occur within two years, biotope sensitivity is therefore 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

Not assessed.

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

A number of studies have investigated the effects of electromagnetic fields on terrestrial oligochaetes, notable earthworms. Some negative effects have been observed e.g. Tkalec *et al*., 2013. However no evidence was found to support an assessment at the pressure benchmark for the marine oligochaetes that characterize this 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

Not relevant.

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

No evidence was found to assess this pressure. Studentowicz (1936) found that the enchytraeid oligochaete *Enchytraeus albidus*, retracted from light, although the worms accumulated at the surface even when illuminated to avoid low oxygen and hydrogen sulpfide. Giere and Pfannkuche (1982) considered that other enchytraeids and tubificids are likely to react in the same way. As the biological assemblage occurs within the sediment and can be deeply buried (to 10cm or more) this pressure is considered ‘Not relevant’.

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

As the tubificid oligochaetes that characterize this biotope have benthic dispersal strategies (via egg cocoons laid on the surface, Giere & Pfannkuche, 1982), water transport is not a key method of dispersal over wide distances, as it is for some marine invertebrates that produce pelagic larvae. The biotope (based on the biological assemblage) is therefore considered to have 'High' resistance to the presence of barriers that lead to a reduction in tidal excursion, resilience is assessed as 'High' (by default) and the biotope is 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 grounding vessels is addressed under 'surface abrasion.

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

Most aquatic oligochaetes have no eyes although a few have simple ocelli (eyspots) which are light receptors. Visual disturbance is not considered relevant to this biotope.

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

Key characterizing species within this biotope are not cultivated or translocated. This pressure is therefore considered 'Not relevant' to this biotope group.

Introduction or spread of invasive non-indigenous species	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

The mobility of the sediment, coupled with the variable salinity may prevent colonization by most non-indigenous species. No examples were found. The polychaete *Marenzellaria viridis* has become established in estuaries in Europe but a recent paper on its impacts where *Tubificoides* were abundant did not report on oligochaete impacts (Delefosse *et al*., 2012).

Sensitivity assessment. As the biotope characteristics are likely to limit colonization of this biotope, resistance is assessed as 'High', resilience as 'High' and the biotope is conisdered to be be 'Not sensitive'. This assessment may need revising based on future surveys or new species colonizing the UK.

Introduction of microbial pathogens	High Q: High A: High C: Low	High Q: High A: High C: High	Not sensitive Q: High A: High C: Low

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

Sensitivity assessment. Based on the lack of evidence for mass mortalities in oligochaetes from microbial pathogens resistance is assessed as 'High' and resilience as 'High', by default, so that the biotope is assessed as 'Not sensitive'.

Removal of target species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

No species within the biotope are targeted by commercial or recreational fishers or harvesters. This pressure is therefore considered 'Not relevant'.

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

Incidental removal of the characterizing species would alter the character of the biotope and the delivery of ecosystem services such as secondary production and bioturbation. Populations of oligochaetes provide food for macroinvertebrates fish and birds. For example up to 67% of flounder and plaice stomachs examined from the Medway estuary (UK) (Van den Broek, 1978) contained the remains of *Tubificoides benedii* (studied as *Peloscolex benedeni)* and shrimps which in turn support higher trophic levels (predatory birds and fish). For some migratory birds the characterizing species *Tubificoides benedii* can form an important part of the diet during winter (Bagheri & McLusky, 1984). Polychaetes and crustaceans are also predators of oligochaetes and may significantly reduce numbers (Giere & Pfannkuche, 1982 and references therein). The loss of the oligochaete population could, therefore, impact other trophic levels.

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

Bibliography

Bagheri, E. & McLusky, D., 1982. Population dynamics of oligochaetes and small polychaetes in the polluted forth estury ecosystem. *Netherlands Journal of Sea Research*, **16**, 55-66.

Bagheri, E.A. & McLusky, D.S., 1984. The oxygen consumption of *Tubificoides benedeni* (Udekem) in relation to temperature and its application to production biology. *Journal of Experimental Marine Biology and Ecology*, **78**, 187-197.

Bamber, R.N. & Spencer, J.F. 1984. The benthos of a coastal power station thermal discharge canal. *Journal of the Marine Biological Association of the United Kingdom*, **64**, 603-623.

Birtwell, I.K. & Arthur, D.R., 1980. The ecology of tubificids in the Thames Estuary with particular reference to *Tubifex costatus* (Claparède). In *Proceedings of the first international symposium on aquatic oligochaete biology, Sydney, British Colombia, Canada, May 1-4, 1979. Aquatic oligochaete biology* (ed. R.O. Brinkhurst & D.G. Cook), pp. 331-382. New York: Plenum Press

Bolam, S. & Whomersley, P., 2003. Invertebrate recolonization of fine-grained beneficial use schemes: An example from the southeast coast of England. *Journal of Coastal Conservation*, **9** (2), 159-169.

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

Bouchet, V.M. & Sauriau, P.-G., 2008. Influence of oyster culture practices and environmental conditions on the ecological status of intertidal mudflats in the Pertuis Charentais (SW France): A multi-index approach. *Marine Pollution Bulletin*, **56** (11), 1898-1912.

Brinkhurst, R. & Kennedy, C., 1962. Some aquatic Oligochaeta from the Isle of Man with special reference to the Silver Burn Estuary. *Archive fur Hydrobiologie*, **58** (3), 367-766.

Commito, J.A. & Boncavage, E.M., 1989. Suspension-feeders and coexisting infauna: an enhancement counterexample. *Journal of Experimental Marine Biology and Ecology*, **125** (1), 33-42.

Commito, J.A., 1987. Adult-larval interactions: predictions, mussels and cocoons. *Estuarine, Coastal and Shelf Science*, **25**, 599-606.

Delefosse, M., Banta, G.T., Canal-Vergés, P., Penha-Lopes, G., Quintana, C.O., Valdemarsen, T. & Kristensen, E., 2012. Macrobenthic community response to the *Marenzelleria viridis* (Polychaeta) invasion of a Danish estuary. M*arine Ecology Progress Series*, **461**, 83-94.

Dernie, K.M., Kaiser, M.J., Richardson, E.A. & Warwick, R.M., 2003. Recovery of soft sediment communities and habitats following physical disturbance. *Journal of Experimental Marine Biology and Ecology*, **285-286**, 415-434.

Elliot, M., Nedwell, S., Jones, N.V., Read, S.J., Cutts, N.D. & Hemingway, K.L., 1998. Intertidal sand and mudflats & subtidal mobile sandbanks (Vol. II). An overview of dynamic and sensitivity for conservation management of marine SACs. *Prepared by the Scottish Association for Marine Science for the UK Marine SACs Project.*

EMU, 1992. An experimental study on the impact of clam dredging on soft sediment macro invertebrates. English Nature Research Reports. No 13.

Gamenick, I., Jahn, A., Vopel, K. & Giere, O., 1996. Hypoxia and sulphide as structuring factors in a macrozoobenthic community on the Baltic Sea shore: Colonization studies and tolerance experiments. *Marine Ecology Progress Series*, **144**, 73-85.

Giere, O., 1977. An ecophysiological approach to the microdistribution of meiobenthic Oligochaeta. I. *Phallodrilus monospermathecus* (Knöllner)(Tubificidae) from a subtropical beach at Bermuda. *Biology of benthic organisms.* Pergamon Press New York, 285-296.

Giere, O., 2006. Ecology and biology of marine oligochaeta–an inventory rather than another review. *Hydrobiologia*, **564** (1), 103-116.

Giere, O. & Pfannkuche, O., 1982. Biology and ecology of marine Oligochaeta, a review. *Oceanography and Marine Biology*, **20**, 173-309.

Giere, O., Preusse, J. & Dubilier, N. 1999. *Tubificoides benedii* (Tubificidae, Oligochaeta) - a pioneer in hypoxic and sulfide environments. An overview of adaptive pathways. *Hydrobiologia*, **406**, 235-241.

Gillett, D.J., Holland, A.F. & Sanger, D.M., 2007. On the ecology of oligochaetes: monthly variation of community composition and environmental characteristics in two South Carolina tidal creeks. *Estuaries and Coasts*, **30** (2), 238-252.

Goulletquer, P. & Heral, M., 1997. Marine molluscan production trends in France: from fisheries to aquaculture. *NOAA Tech. Rep. NMFS*, **129**.

Gray, J.S., 1971. The effects of pollution on sand meiofauna communities. *Thalassia Jugoslovica*, **7**, 76-86.

Hall, J.A. & Frid, C.L.J., 1995. Response of estuarine benthic macrofauna in copper-contaminated sediments to remediation of sediment quality. *Marine Pollution Bulletin*, **30**, 694-700.

Haskoning UK Ltd. 2006. Investigation into the impact of marine fish farm deposition on maerl beds. *Scottish Natural Heritage Commissioned Report No.* 213 (ROAME No. AHLA10020348).

Hunter, J., & Arthur, D.R., 1978. Some aspects of the ecology of *Peloscolex benedeni* Udekem (Oligochaeta: Tubificidae) in the Thames estuary. *Estuarine and Coastal Marine Science*, **6**, 197-208.

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/

Leppäkoski, E. & Lindström, L., 1978. Recovery of benthic macrofauna from chronic pollution in the sea area off a refinery plant, southwest Finland. *Journal of the Fisheries Board of Canada*, **35** (5), 766-775.

Leppäkoski, E., 1975. Assessment of degree of pollution on the basis of macrozoobenthos in marine and brackish water environments. *Acta Academiae Åboensis*, Series B, **35**, 1-90.

Linke, O., 1939. Die Biota des Jadebusenwatts. *Helgolander Wissenschaftliche Meeresuntersuchungen*, **1**, 201-348.

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.

McLusky, D.S., Teare, M. & Phizachlea, P., 1980. Effects of domestic and industrial pollution on distribution and abundance of aquatic oligochaetes in the Forth estuary. *Helgolander Wissenschaftliche Meeresuntersuchungen*, **33**, 384-392.

Nugues, M., Kaiser, M., Spencer, B. & Edwards, D., 1996. Benthic community changes associated with intertidal oyster cultivation. *Aquaculture Research*, **27** (12), 913-924.

Parr, W., Clarke, S.J., Van Dijk, P., Morgan, N., 1998. Turbidity in English and Welsh tidal waters. Report No. CO 4301/1 to English Nature.

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.

Rygg, B., 1985. Effect of sediment copper on benthic fauna. *Marine Ecology Progress Series*, **25**, 83-89.

Sheehan, E., Coleman, R., Thompson, R. & Attrill, M., 2010. Crab-tiling reduces the diversity of estuarine infauna. *Marine Ecology Progress Series*, **411**, 137-148.

Studentowicz, J., 1936. Der Einfluss des Lichtes auf das Verhalten des Oligochaeten *Enchytraeus albidus* Henle: *Bulletin International Academy of Polish Science Letters, Series B*. .

Tang, M. & Kristensen, E., 2010. Associations between macrobenthos and invasive cordgrass, *Spartina anglica*, in the Danish Wadden Sea. *Helgoland Marine Research*, **64** (4), 321-329.

Van den Broek, W., 1978. Dietary habits of fish populations in the Lower Medway Estuary. *Journal of Fish Biology*, **13** (5), 645-654.

Van Hoey, G., Guilini, K., Rabaut, M., Vincx, M. & Degraer, S., 2008. Ecological implications of the presence of the tube-building polychaete *Lanice conchilega* on soft-bottom benthic ecosystems. *Marine Biology*, **154** (6), 1009-1019.

Verdonschot, P., Smies, M. & Sepers, A., 1982. The distribution of aquatic oligochaetes in brackish inland waters in the SW Netherlands. *Hydrobiologia*, **89** (1), 29-38.

Whomersley, P., Huxham, M., Bolam, S., Schratzberger, M., Augley, J. & Ridland, D., 2010. Response of intertidal macrofauna to multiple disturbance types and intensities – an experimental approach. *Marine Environmental Research*, **69** (5), 297-308.

Zühlke, R. & Reise, K., 1994. Response of macrofauna to drifting tidal sediments. *Helgoländer Meeresuntersuchungen*, **48** (2-3), 277-289.