Infralittoral mobile sand in variable salinity (estuaries)

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

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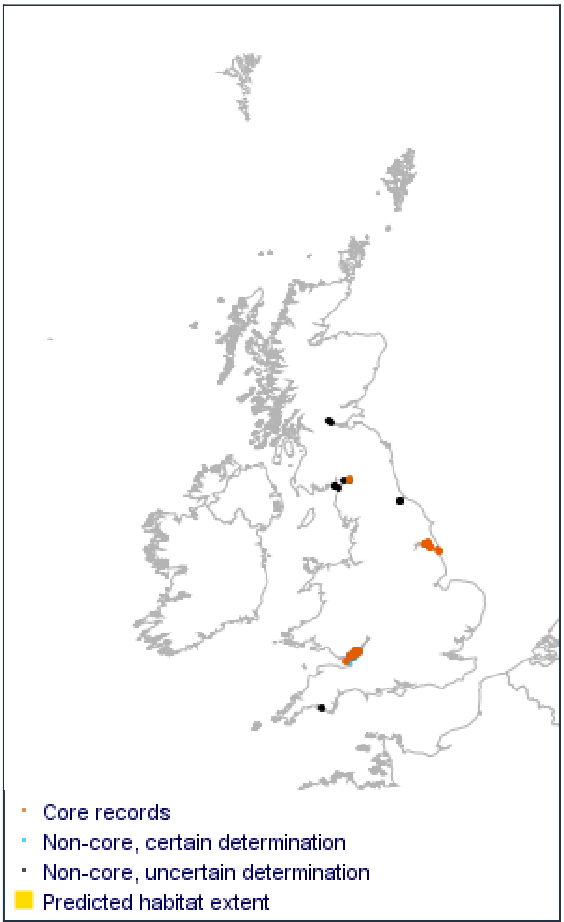

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Dr Heidi Tillin & Dr Matt Ashley **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A5.221	Infralittoral mobile sand in variable salinity (estuaries)
JNCC 2015	SS.SSa.SSaVS.MoSaVS	Infralittoral mobile sand in variable salinity (estuaries)
JNCC 2004	SS.SSa.SSaVS.MoSaVS	Infralittoral mobile sand in variable salinity (estuaries)
1997 Biotope	SS.IGS.EstGS.MobRS	Sparse fauna in reduced salinity infralittoral mobile sand

Description

Very mobile sand in areas of strong tidal currents and variable salinity. No stable community is able to develop within this extremely mobile and abrasive habitat. The fauna encountered in this habitat consists of epifaunal crustaceans or relatively low numbers of robust species, such as the isopod *Eurydice pulchra* or *Mesopodopsis slabberi*. The polychaete *Capitella capitata* may occur frequently in some areas. Other taxa such as the polychaetes *Eteone* spp. and *Arenicola marina*, the mysid *Neomysis integer* and the amphipods *Bathyporeia* spp. and *Haustorius arenarius* may also be washed in from adjacent communities. This biotope is found in tidal channels of estuaries and areas where water movement keeps silt and mud in suspension, and excludes even the more robust infauna. If oligochaetes, polychaetes and bivalves are present in any numbers within this habitat type then care must be taken to avoid the inclusion of juvenile or spat recruitment counts which may mask the presence of this biotope. This is particularly relevant as sampling usually occurs at slack water periods when settlement takes place. (Information from Connor *et al.*, 2004; JNCC, 2015).

Depth range

0-5 m, 5-10 m, 10-20 m

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

Very mobile sand in areas of strong tidal currents and variable salinity. No stable community is able to develop within this extremely mobile and abrasive habitat. The fauna encountered in this habitat consists of epifaunal crustaceans or relatively low numbers of robust species, such as the isopod *Eurydice pulchra*. The polychaete *Capitella capitata* may occur frequently in some areas. Other taxa such as the polychaetes *Eteone* spp. and *Arenicola marina*, the mysid *Neomysis integer* and the amphipods *Bathyporeia* spp. and *Haustorius arenarius* may also be washed in from adjacent communities. This biotope is found in tidal channels of estuaries and areas where water movement keeps silt and mud in suspension, and excludes even the more robust infauna.

Resilience and recovery rates of habitat

Biotopes in the upper reaches of estuaries are characterized by strong tidal streams and mobile sediments that create inhospitable conditions for the development of stable communities. They are home to impoverished animal communities with high abundances of opportunistic species such as *Capitella capitata* that can tolerate low and variable salinities and which typically mature rapidly and have short lifespans.

Capitella capitata is a classic opportunist species possessing life history traits of rapid development, many reproductions per year, high recruitment and high mortality rates (Grassle & Grassle, 1974; McCall, 1977). In favorable conditions maturity can be reached in <3 months and growth rate is estimated to be 30 mm per year. Adult potential dispersal is up to 1 km. The species complex displays reproductive variability, planktonic larvae are able to colonize newly disturbed patches but after settlement the species can produce benthic larvae brooded within the adult tube to rapidly increase the population before displacement by more competitive species (Gray, 1979). Shull (1997) demonstrated that recolonization occurs by larval settlement, bedload transport and by burrowing. Thus, when conditions are suitable, the time for the community to reach maturity is likely to be less than six months. Bolam & Fernandes (2002) and Shull (1997) noted that *Capitella capitata* can colonize azoic sediments rapidly in relatively high numbers. Experimental studies using defaunated sediments, have shown that on small scales *Capitella* can recolonize to background densities within 12 days (Grassle & Grassle, 1974; McCall, 1977). In Burry Inlet, Wales, tractor towed cockle harvesting led to a reduction in density of some species but *Capitella capitata* had almost trebled its abundance within the 56 days in a clean sandy area (Ferns *et al*., 2000).

Resilience assessment. As the characterizing species reaches maturity within a year, and proceed to produce more than one generation, recovery is likely to be rapid. In terms of the species present the biotope may be recognizable within 1-2 years following defaunation. Resilience is therefore assessed as 'High' for all levels of impact.

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

This biotope is not characterized by a stable community. The polychaete *Capitella capitata* may be abundant in some exampls. *Capitella capitata* is a cosmopolitan species in coastal marine and estuarine soft sediment systems. Grassle and Grassle (1976) used electrophoretic enzyme analysis to determine that the global population is actually made up of several genetically distinct (and apparently genetically isolated) sibling species whose distributions overlap such that local *Capitella capitata* populations actually consist of a number of co-occurring sibling species. Within the complex tolerances may vary and local acclimation is possible. *Capitella capitata* has also been recorded in extreme environments around hydrothermal vents (Gamenick & Giere, 1997) which suggests that the species complex would be relatively tolerant to an increase in temperature. Experimental evaluation of the effects of combinations of varying salinities and temperature on *Capitella capitata* were carried out by Redman (1985) and Warren (1977). Redman (1985) found that, length of life decreased as follows: 59 weeks at mid-temperature and salinity (15°C, 25ppt); 43 weeks at high temperature & high salinity (18°C, 30ppt); 33 weeks at lower temperature & high salinity (12°C, 30ppt); 17 weeks at high temperature & low salinity (18°C, 20ppt). Redman (1985) also found that net reproduction (Ro: the mean number of offspring produced per female at the end of the cohort) decreased as follows: 41.75 control; 36.69 under high salinity, high temperature; 2.19 high temperature, low salinity; 2.16 low temperature, high salinity. Therefore, a combination of changes in temperature and salinity may decrease the viability of the population. Warren (1977) used individual worms collected from Warren Point (south-west England) to test response to high and low temperatures. Worms were acclimated to 10°C for 10 days and subsequently heated in a water bath to experienced a rise in temperature of 1 °C per 5 min. When the temperature had reached 28 °C worms were removed at 0.5 °C intervals and returned to a constant temperature of 10 °C. The percentage mortality after 24 h was calculated. Larvae were removed from the maternal tube and tested using the same method. The experiments indicated that temperatures above 30 °C were most critical; the upper lethal temperature was 31.5 °C for adult worms and a little higher for the larvae.

Sensitivity assessment. Typical surface water temperatures around the UK coast vary, seasonally from 4-19 °C (Huthnance, 2010) although in estuaries and other shallow waters the temperature range may exceed this due to summer warming and winter cooling. The biotope, based on the characterizing species is considered to tolerate a 2 °C increase in temperature for a year. he experimental studies by Redman (1985) suggest that changes in temperature may reduce the life-span of *Capitella capitata*, however this effect is not considered to alter the character of the biotope as the short life cycle of this species should lead to rapid replenishment of the population. The experiments by Warren (1977) suggest that both the chronic and acute increases in temperature would not exceed the thermal tolerance of *Capitella capitata*. The biotope is therefore assessed as '**Not sensitive**' (resistance and resilince are both '**High'.**

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

This biotope is not characterized by a stable community. but some exampls may have abundant *Capitlla capitata*. Wu *et al.* (1988) collected *Capitella capitata* individuals at seawater temperatures of -2°C that harboured mature oocytes indicating reproductive activity even under low temperatures.Warren (1977) used individual worms collected from Warren Point (south-west England) to test response to high and low temperatures. Worms were acclimated to 10°C for 10 days prior to testing. The worms were cooled in a water bath to experience a decrease in temperature of 1 °C per 5 min. When the final temperature was reached, worms were removed at 0.5 °C intervals and returned to a constant temperature of 10 °C. The percentage mortality after

24 h was calculated. Each experiment was repeated once. Larval *Capitella capitata* were removed from the maternal tube and tested using the same method. Both adults and larvae of *Capitella capitata* were tolerant of low temperatures, 50 % of the adults and 65 % of the larvae surviving at -1°C.

Sensitivity assessment. Within the current temperature range, resistance to an acute decrease in temperature at the pressure benchmark level is assessed as '**High**', Resilience is '**High**' and therefore, the biotope is assessed as '**Not sensitive**'.

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

Salinity is a key factor structuring the biotope, therefore, an increase in salinity at the pressure benchmark could lead to changes in habitat suitability resulting in changes in distribution and extent. Some seasonal changes in salinity occur within estuaries and such shifts may be part of the natural temporal variability. For example, the location of the biotope SS.SSa.SSaVS.NintGam within the estuary may also shift upstream or downstream on a seasonal or yearly basis related in part to the freshwater flow into the estuary (JNCC, 2015) as has been noted in the Humber (Allen *et al*. 2003).

Capitella capitata and other associated species occur intertidally and in areas with limited water exchange such as lagoons: these habitats may experience short-term increases in salinity due to evaporation and some resistance is therefore expected with local acclimation possible.

Sensitivity assessment. Salinity is a key factor structuring the biotope and changes at the pressure benchmark are likely to lead to changes in species distribution and abundance within estuarine systems. The characterizing species *Capitella capitata* display high resistance to a change to full salinity. A change to full salinity may lead to replacement of the SS.SSa.SSaVS.MoSaVS by the biotope SS.SSa.IFiSa.IMoSa as this biotope occurs in similar conditions in full salinities (JNCC, 2015). Biotope resistance is therefore, assed as '**Low**', resilience (following rstoration of salinity regime) is '**High**' and sensitivity is assessed as '**Low**'.

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

Salinity is a key factor structuring the biotope a decrease in salinity at the pressure benchmark will lead to changes in habitat suitability leading to a shift in distribution. Some seasonal changes in salinity occur within estuaries and such shifts may be part of the natural temporal variability. For example, the location of the biotope SS.SSa.SSaVS.NintGam within the estuary may also shift upstream or downstream on a seasonal or yearly basis related in part to the freshwater flow into the estuary (JNCC, 2015) as has been noted in the Humber (Allen *et al*., 2003).

Locations close to the freshwater source in an estuary in southern, Portugal had higher abundances of the characterizing polychaete *Capitella capitata* than locations in more saline conditions (Silva *et al*., 2012). Opportunistic, deposit feeding polychaetes, such as *Capitella capitata* tolerate stressful conditions, and often out-compete more sensitive species due to tolerance of decreased salinity (or other pressures such as organic enrichment) (Newell, 1998).

Sensitivity assessment. Characterizing species, *Capitella capitata*, of the biotope

SS.SSa.SSaVS.MoSaVs, show 'High' Resistance and so 'High' resilience to lower salinities, however reductions in salinity at the pressure benchmark to low salinity (<18ppt) may result in a transition to the biotope SS.SSaSSaVS.NintGam, biotope resistance is assessed as '**Low**', resilience is assessed as '**High**' (following restoratioon of the salinity regime) and sensitivity is assessed as '**Low'.**

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

This biotope occurs in sheltered locations where tidal flow is normally more important than wave action as a structuring factor. Tidal flow ranges from weak (<0.5 m/s) to strong (1.5- 3 m/s) occur in the biotope SS.SSa.SSaVS.MoSaVs suggesting changes in flow velocity at the prssure benchmark are unlikely to impact biotopes that occur in th mid-range. Stronger currents lead to constant change in the size shape and position of sand banks and in some areas e.g. in the Solway Firth where tidal streams are particularly strong, sandbanks may move considerably over one tidal cycle (Perkins, 1974).

Sensitivity assessment. Resistance of SS.SSa.SSaVS.MoSaVS is likely to be '**High**', Resilience is '**High**' by default and Sensitivity assessed as '**Not Sensitive'** as the biotope occurs across a range of flow velocities.

Emergence regime changes	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant as the biotope occurs in depths of 0-5 m or deeper. Owing to the infaunal habit and/or mobility, the characterizing species are likely to be offered considerable protection or would move away to seek more favourable conditions if the limit of the biotope became intertidal , however the biotope would be lost.

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

This biotope is found on shores that are judged to be moderately exposed, sheltered or very sheltered to wave action (JNCC, 2015). The presence of this biotope across these three categories is considered to indicate (by proxy), that increases or decreases in wave exposure at the pressure benchmark are unlikely to lead to alterations to the biotope. Resistance is therefore assessed as '**High**' and resilience as '**High**' (by default) so that 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.

Levels of contaminants that exceed the pressure benchmark may cause impacts. For most metals, toxicity to crustaceans increases with decreased salinity and elevated temperature, therefore marine species living within their normal salinity range may be less susceptible to heavy metal pollution than those living in salinities near the lower limit of their salinity tolerance (McLusky *et al.*, 1986). Jones (1973; 1975b) found that mercury (Hg) and copper (Cu) reacted synergistically with changes in salinity and increased temperature (10°C) to become increasingly toxic to species of isopod, including *Eurydice pulchra*.

The sediment grade and the hydrographic conditions within the biotope are responsible for a high dispersion, so that instances of severe pollution are less in comparison to regions with weaker tidal flow. Bryan & Gibbs (1983) reported lower sediment-metal concentrations in sandy areas than mud near the mouth of Restronguet Creek, a branch of the Fal Estuary system which is heavily contaminated with metals.

For most metals, toxicity to crustaceans increases with decreased salinity and elevated temperature. Consequently amphipod species living within their normal salinity range may be less susceptible to heavy metal pollution than those living in salinities near the lower limit of their salinity tolerance (McLusky *et al.*, 1986). Amphipod species characterizing the variations of the biotope in transition zones between freshwater and brackish environments are thereby, likely to suffer greater impacts from contamination.

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.

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.

Oil spills resulting from tanker accidents have caused deterioration of sandy communities in the intertidal and shallow sublittoral. Subtidal sediments, however, may be at less risk from oil spills unless oil dispersants are used, or if wave action causes dispersion of oil into the water column and sediment mobility drives oil in to the sediment (Elliott *et al.*, 1998). Microbial degradation of the oil within the sediment would increase the biological oxygen demand and oxygen within the sediment may become significantly reduced.

Species within the biotope have been reported to be intolerant of oil pollution, e.g. amphipods (Suchanek, 1993). After the *Amoco Cadiz* oil spill there was a reduction in both the number of amphipod species and the number of individuals (Cabioch *et al.*, 1978). Initially, significant mortality would be expected, attributable to toxicity. Amphipod populations have been reported not return to pre-spill abundances for five or more years, which is most likely related to the persistence of oil within sediments (Southward, 1982).

Multivariate analysis showed that the Prestige oil spill scarcely affected the macroinfaunal community structure during the study period (2003-2009) and its effect was limited just to the first campaign (2003), six months after the Prestige accident (Junoy *et al.*, 2013). Opportunistic species such *Capitella capitata* have been shown to increase in abundance close to sources of contamination. High numbers of *Capitella capitata* have been recorded in hydrocarbon contaminated sediments (Ward & Young, 1982; Olsgard, 1999; Petrich & Reish, 1979) and colonization of areas defaunated by high hydrocarbon levels may be rapid (Le Moal, 1980). After a major spill of fuel oil in West Virginia *Capitella capitata* increased dramatically alongside large increases in *Polydora ligni* and *Prionospio* sp. (Sanders *et al*. 1972, cited in Gray 1979). Experimental studies adding oil to sediments have found that *Capitella capitata* increased in abundance initially although it was rarely found in samples prior to the experiment (Hyland, 1985).

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.

Bioaccumulation of conservative contaminants may occur within the infauna, but in coarse sand beaches contaminants are unlikely to accumulate owing to a relative absence of organic matter. Direct toxic effects would therefore be expected. In general, crustaceans are widely reported to be intolerant of synthetic chemicals (Cole *et al*., 1999) and low resistance to some specific chemicals has been observed in amphipods. Powell (1979) inferred from the known susceptibility of Crustacea to synthetic chemicals and other non-lethal effects, that there would probably also be a deleterious effect on isopod fauna as a direct result of chemical application. Toxicity tests conducted by Smith (1968) indicated that survival of *Eurydice pulchra* after oil detergent treatment was above average for crustaceans. All were killed at about 10 ppm BP 1002 after 24 hours exposure, whilst at 5 ppm four out of five individuals survived when transferred to clean seawater. However, in the field a proportion of the *Eurydice pulchra* population survived exposure to lethal concentrations of BP 1002, both in the sand and water.

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

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**.

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

The mobile sands that characterize this biotope may have relatively high oxygen concentration and lack a black reducing layer (JNCC, 2015).

Sensitivity assessment. The species characterizing the biotope are mobile and able to migrate vertically to escape unsuitable conditions. Biotope resistance is therefore assessed as '**High**' and Resilience as '**High'** (by default) so that the biotope is considered to be '**Not sensitive'**.

Nutrient enrichment

Resistance	Resilience	Sensitivity
High Q: High A: Medium C: Medium	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

This pressure relates to increased levels of nitrogen, phosphorus and silicon in the marine environment compared to background concentrations. The benchmark is set at compliance with WFD criteria for good status, based on nitrogen concentration (UKTAG, 2014).

In-situ primary production is limited to microphytobenthos within and on sediments and the high levels of sediment mobility may limit the level of primary production as abrasion would be likely to damage diatoms (Delgado *et al*., 1991). The characterizing amphipods feed on epipsammic diatoms attached to the sand grains (Nicolaisen & Kanneworff, 1969). Both these groups may benefit from slight nutrient enrichment if this enhanced primary production.

Sensitivity assessment. Nutrient level is not a key factor structuring the biotope at the pressure benchmark. In general however, primary production is low and this biotope is species poor and characterizing species may be present at low abundances (depending on wave exposure). Biotope resistance is therefore assessed as '**High**', resilience as **'High'** (by default) and the biotope is considered to be **'Not sensitive**' at the pressure benchmark that assumes compliance with good status as defined by the WFD. Changes in nutrient status may indirectly affect this biotope where these result in changes in diatom production and inputs of macroalagal debris.

Organic enrichment

Resistance	Resilience	Sensitivity
High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

The biotope occurs in mobile sand sediments where wave action leads to particle sorting, in-situ primary production is restricted to microphytobenthos although sediment mobility may restrict production levels (Delgado *et al*., 1991).

The isopod *Eurydice pulchra* is an aggressive and very mobile predator, feeding on polychaetes and amhipods, including *Bathyporiea pilosa*, *Bathyporeia sarsi* and *Scolelepuis squamata* (Jones, 1968). An increase in secondary production of prey species would therefore be of benefit to this species.

An increase in organic enrichment that exceeded the pressure benchmark may impact the habitat and biological assemblage, particularly in more sheltered areas where deposits can accumulate. For instance, prior to the introduction of a sewage treatment scheme in the Firth of Forth (Scotland) , the communities of several sandy beaches were considerably modified by gross sewage pollution (Read *et al*., 1983). The west end of Seafield beach exhibited extremely reduced diversity with a community dominated by *Scolelepis fuliginosa* and *Capitella capitata*, to the almost exclusion of all other species of macrofauna. However, at Portobello beach, a reduction in the number of species was recorded and the presence of a 'dominant' replacement community was less obvious. Furthermore, in 1977, before the introduction of the sewage scheme, meiofauna population counts at Seafield and Portobello were also conspicuously lower than for other Scottish beaches (McIntyre, 1977). Many of the major taxa commonly associated with marine intertidal meiobenthos were scarce or absent. Only nematodes, gastrotriches, harpacticoids and turbellarians were commonly identified from samples, nematodes being the most abundant taxon. Following sewage pollution abatement in 1977, dramatic changes in the macrofauna occurred. The *Scolelepis* / *Capitella* community declined steadily throughout 1978-1979, so that by spring 1980 species normally associated with 'cleaner' sandy beaches were recorded e.g. *Microthalmus* sp., *Ophiodromus flexuosus*, *Eulalia viridis*, *Eurydice pulchra Monoculodes* sp., but not at pre-impact abundances. There was also an increase in meiofaunal diversity and reduction in dominance by certain taxa.

Sensitivity assessment. At the pressure benchmark organic inputs are likely to represent a food subsidy for the characterizing species and are unlikely to significantly affect the structure of the biological assemblage or impact the physical habitat. Biotope sensitivity is therefore assessed as '**High**' and resilience as '**High'** (by default) and the biotope is therefore 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 and estuarine habitats and benthic species are considered to have a resistance of '**None**' to this pressure and to be unable to recover from a permanent loss of habitat (resilience is '**Very Low'**). Sensitivity within the direct spatial footprint of this pressure is therefore **'High'**. Although no specific evidence is described confidence in this assessment is '**High**', due to the incontrovertible nature of this pressure.

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

This biotope is only found in upper reaches of marine inlets, especially estuaries, where water movement is moderately strong, allowing the sedimentation of sand but not the finer silt fraction. A change to a hard or artificial substratum would significantly alter the character of the biotope. The biotope is therefore considered to have '**No**' resistance to this pressure, recovery is assessed as '**Very low**', as the change at the pressure benchmark is permanent. Biotope sensitivity is therefore assessed as '**High**'.

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

The benchmark for this pressure refers to a change in one Folk class. The pressure benchmark originally developed by Tillin *et al.*, (2010) used the modified Folk triangle developed by Long (2006) which simplified sediment types into four categories: mud and sandy mud, sand and muddy sand, mixed sediments and coarse sediments. The change referred to is therefore a change in sediment classification rather than a change in the finer-scale original Folk categories (Folk, 1954). The change in one Folk class is considered to relate to a change in classification to adjacent categories in the modified Folk triangle. For sand sediments, a change in one folk class may refer to a change to gravels, mixed sediments or muddy sands, sandy muds and muds.

The characterizing species, *Capitella capitata* was found in fine and medium grain size sediments and was almost completely absent in sediments without mud in the Belgium part of the North Sea (Degraer *et al.*, 2006). This suggests that a change to muddy sand is likely to result in increased abundance but a change to gravelly sand is likely to lead to reduced abundance. A change in sediment type would result in reclassification of the biotope (JNCC, 2015) and a change to mixed or fine sediments would likely result in the establishment of a species rich and more diverse community (depending on other habitat factors). Biotope resistance is, therefore, assessed as '**None**' and resilience as '**Very low**' as the change at the pressure benchmark is permanent. Sensitivity is therefore '**High**'.

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 process of extraction is considered to remove all biological components of the biotope group. If extraction occurred across the entire biotope, loss of the biotope would occur. Recovery would require substratum to return to sand. *Capitella capitella* are opportunistic species and are likely to recolonize the area rapidly.

Sensitivity assessment. Resistance of the biotope to extraction **is 'None',** in mobile sands recovery is likely to be rapid and resilience is assessed as '**High**' and biotope sensitivity is assessed as '**Medium**'.

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

Mean response of infauna and epifauna communities to fishing activities is shown to be much more negative in mud and sand communities than other habitats Collie *et al*. (2000). *Capitella capitata*, are soft bodied relatively fragile species inhabiting mucus tubes close to the sediment surface. Abrasion and compaction of the surficial layer may damage individuals. *Capitella capitata* has been categorised through literature and expert review, as AMBI fisheries Group IV- a second-order opportunistic species, which are sensitive to fisheries in which the bottom is disturbed. Their populations recover relatively quickly however and benefit from the disturbance, causing their population sizes to increase significantly in areas with intense fisheries (Gittenberger & Van Loon 2011). Chandrasekara and Frid (1996) found that in intertidal muds, along a pathway heavily used for five summer months (ca 50 individuals a day), some species including *Capitella capitata* reduced in abundance. Bonsdorff & Pearson (1997) found that sediment disturbance forced *Capitella capitata* deeper into the sediment, although the species was able to burrow back through the sediment to the surface again.

Sensitivity assessment. This biotope group is present in mobile sands, the associated species are generally present in low abundances and adapted to frequent disturbance suggesting that resistance to surface abrasion would be high. The amphipod and isopod species present are agile swimmers and are characterized by their ability to withstand sediment disturbance (Elliott *et al*. 1998). This characteristic is likely to protect this species from surface abrasion. Resistance is assessed as '**Medium**', as abrasion is unlikely to affect high numbers of the key characterizing species, resilience is assessed as '**High**' and biotope sensitivity is assessed as '**Low**'.

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

This biotope group is present in mobile sands, the associated species are generally present in low abundances and adapted to frequent disturbance suggesting that resistance to abrasion and penetration and disturbance of the sediment would be high. The amphipod species present are agile swimmers and are characterized by their ability to withstand sediment disturbance (Elliott *et al*., 1998).

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

Estuaries where this biotope is often found form can be naturally turbid systems due to sediment resuspension by wave and tide action and inputs of high levels of suspended solids, transported by rivers. The level of suspended solids depends on a variety of factors including: substrate type, river flow, tidal height, water velocity, wind reach/speed and depth of water mixing (Parr *et al*. 1998). Transported sediment including silt and organic detritus can become trapped in the system where the river water meets seawater. Dissolved material in the river water flocculates when it comes into contact with the salt wedge pushing its way upriver. These processes result in elevated levels of suspended particulate material with peak levels confined to a discrete region (the turbidity maximum), usually in the upper-middle reaches, which moves up and down the estuary with the tidal ebb and flow.

Sensitivity assessment. The biological assemblage characterizing this biotope includes infaunal species *Capitella capitata* and mobile amphipods and isopods. Increased and decreased 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**'.

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

As the tidal flow is strong in this biotope and sediments are mobile, a light deposition of finer sediment is likely to be resuspended. *Capitella capitata* has also been categorised through expert and literature review, as AMBI sedimentation Group IV – a second-order opportunistic species, insensitive to higher amounts of sedimentation. Although they are sensitive to strong fluctuations in sedimentation, their populations recover relatively quickly and even benefit. This causes their population sizes to increase significantly in areas after a strong fluctuation in sedimentation (Gittenberger & van Loon 2011). The mobile amphipods and isopods that charactrize this biotope may be abl to surface through a 5cm layer of deposit and strong tidal currents are likely to result in rapid resuspension and removal of fine sediments.

Sensitivity assessment. None of the characterizing species are likely to be significantly impacted by deposition of up to 5 cm of fine material, although a limited percentage of the characterizing amphipod population may suffer mortality from smothering. Resistance is assessed as '**High'**. Resilience as '**High'** and Sensitivity as '**Not sensitive'**.

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

Evidence for the effects of siltation by thick layers of added sediment from beach nourishment is described for the heavy deposition pressure below. The pressure benchmark for light deposition refers to the addition of a relatively thin layer of deposits in a single event. Species adapted to coarse sediments may not be able to burrow through fine sediments, or experienced reduced burrowing ability. For example, Bijkerk (1988, results cited from Essink, 1999) found that the maximal overburden through which the amphipod *Bathyporeia* could migrate was approximately 20 cm in mud and 40 cm in sand. No further information was available on the rates of survivorship or the time taken to reach the surface. As the biotope is associated with wave exposed habitats or those with strong currents, some sediment removal will occur, mitigating the effect of deposition.

Capitella capitata has been categorised through expert and literature review, as AMBI sedimentation Group IV – a second-order opportunistic species, insensitive to higher amounts of sedimentation. Although they are sensitive to strong fluctuations in sedimentation, their populations recover relatively quickly and even benefit. This causes their population sizes to increase significantly in areas after a strong fluctuation in sedimentation (Gittenberger & van Loon 2011).

Leewis *et al*. (2012) investigated the recovery of the characterizing species, *Eurydice pulchra* and *Haustorius arenarius*, following beach nourishment by comparing beaches that had been exposed at different times. The lengths of beach nourished varied from 0.5 kn to > 7 km. Recovery to original abundances appeared to occur within one year for the characterizing species which were in agreement with other studies (Leewis *et al*., 2012 and references therein).

Sensitivity assessment. Overall smothering by fine sediments is likely to result in some mortality of characterizing polychaetes, amphipods and isopods, although most are likely to reposition. Biotope resistance is therefore assessed as **'Low'** and Resilience as '**High,'** biotope sensitivity is therefore assessed as '**Medium**'.

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

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. However, at the benchmark level the community is unlikely to be sensitive to noise and this pressure is '**Not relevant'.**

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

As this feature is not characterized by the presence of primary producers it is not considered that shading would alter the character of the habitat. No specific evidence was found to assess sensitivity of the characterizing species to this pressure. Changes in light level may, however, affect activity rhythms of the invertebrates. Amphipods within the biotope prefer shade and therefore an increase in light may inhibit activity, particularly at night when they emerge from the sediment and are most active (Jelassi *et al.*, 2015; Ayari, 2015). Changes in light are not considered to directly affect the biotope. Resistance is assessed as '**High'** and Resilience is assessed as '**High**'. Biotope sensitivity ids therefore assessed as '**Not sensitive**'.

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

As the amphipods and isopods that characterize this biotope have benthic dispersal strategies (via brooding), water transport is not a key method of dispersal over wide distances, as it is for some marine invertebrates that produce pelagic larvae. Barriers that limit tidal excursion and flushing may reduce connectivity or help to retain larvae.

Sensitivity assessment. The biotope (based on the biological assemblage) is 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**'.

	Resistance	Resilience	Sensitivity
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'.

	Resistance	Resilience	Sensitivity
Visual disturbance	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not sensitive Q: NR A: NR C: NR

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 **'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

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

	Resistance	Resilience	Sensitivity
Introduction or spread of invasive non-indigenous species	Medium Q: Medium A: Medium C: Medium	Medium Q: Medium A: Medium C: Medium	Medium Q: Medium A: Medium C: Medium

Limited evidence was available to assess the sensitivity of this biotope. Any invasive species would have to tolerate variable salinity and the mobile sediments that characterizes this biotope group and this will exclude species only able to survive in fully marine conditions and/or that require hard substratum. The North American amphipod *Gammarus tigrinus* was detected in the north-eastern Baltic Sea in 2003 and has rapidly expanded into European waters since (Jänes *et al*., 2015.). Native gammarids, such as *Gammarus salinus* have almost disappeared from some habitats of the northeastern Baltic Sea and the competition for space between the invasive *Gammarus tigrinus* the native *Gammarus salinus* has been a contributing factor in certain habitats (Kotta *et al*. 2011). Competition for space alone did not explain the mass disappearance of *Gammarus salinus* as *Gammarus tigrinus* did not out-compete *Gammarus salinus* in all Baltic Sea habitats, limiting confidence in the evidence. However, *Gammarus tigrinus* has been identified in many UK estuaries and coasts and appears likely to influence species composition in the biotope (NBN, 2016).

Sensitivity assessment. Limited evidence was available for all characterizing species in relation to this pressure. *Gammarus tigrinus* displays faster reproduction and is a voracious predator that is abundant in dilute, and more turbid sites. *Gammarus tigrinus* appears to be competitively superior to native gammarids and may alter the amphipod species encountered in this biotope that are washed in from adjacent communities. As the biotope classification is unlikely to change, the resistance of the assessed biotopes is **'High'**, resilience is **'High'** and the biotope is assessed as **'Not sensitive'.**

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

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

Amphipods may also be infected by a number of parasites or pathogens that alter population numbers through changes in host condition, growth, behaviour and reproduction (Green Extabe & Ford, 2014). Infection by acanthocephalan larvae, for example, may alter behaviour and responses of gammarid amphipods (Bethel & Holmes, 1977).

Sensitivity assessment. No evidence was found for pathogen/parasite outbreaks that may result in mass-mortalities in the characterizing species and this pressure is not assessed. Sensitivity assessmentBased on the lack of evidence for mass mortalities in *Capitella capitata* and 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 characterizing 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	Medium Q: Low A: NR C: NR	High Q: High A: Low C: High	Low Q: Low A: Low C: Low

The loss of the key characterizing species through unintentional removal would alter the character of the biotope. The ecosystem services such as secondary production and food for higher trophic levels would be lost. .

Sensitivity assessment. Biotope resistance to loss of the characterizing species is assessed as ‘**Low**’ as the burrowing lifestyle and mobility of species mean that a proportion of the population may escape incidental removal. Resilience is assessed as ‘**High**’ based on in-situ recovery and migration from adjacent populations and sensitivity is therefore assessed as ‘**Low**’. Despite the loss of a high proportion of the characterizing species the biotope would still be classified as belonging to the SS.SSa.SSaVS.MoSaVS group as some examples, particularly those with strong tidal currents, contain few species at low abundance (JNCC, 2015).

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.

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

Allen, J., Boyes, S., Burdon, D., Cutts, N., Hawthorne, E., Hemingway, K., Jarvis, S., Jennings, K., Mander, L., Murby, P., Proctor, N., Thomson, S. & Waters, R., 2003. The Humber Estuary: A Comprehensive Review of Its Nature Conservation Interest. *English Nature Research Reports No. 547. English Nature, Peterborough.*

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

Arndt, E.A., 1991. Ecological, physiological and historical aspects of brackish water fauna distribution. In: *Estuaries and coasts: spatial and temporal intercomparisons. Estuarine and coastal sciences association 19th symposium*, (ed. M. Elliot & J.P. Ducrotoy). Olsen & Olsen.

Astthorsson, O.S., 1980. *The life history and ecological energetics of* Neomysis integer *(Leach) (Crustacea, Mysidacea).* , Ph.D. thesis, University of Aberdeen.

Ayari, A., Jelassi, R., Ghemari, C. & Nasri-Ammar, K., 2015. Locomotor activity patterns of two sympatric species *Orchestia montagui* and *Orchestia gammarellus* (Crustacea, Amphipoda). *Biological Rhythm Research*, **46** (6), 863-871.

Bamber, R.N. & Henderson, P.A., 1994. Seasonality of caridean decapod and mysid distribution and movements within the Severn Estuary and Bristol Channel. *Biological Journal of the Linnean Society*, **51** (1-2), 83-91.

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

Bijkerk, R., 1988. Ontsnappen of begraven blijven: de effecten op bodemdieren van een verhoogde sedimentatie als gevolg van baggerwerkzaamheden: literatuuronderzoek: RDD, Aquatic ecosystems.

Bolam, S.G. & Fernandes, T.F., 2002. Dense aggregations of tube-building polychaetes: response to small-scale disturbances. *Journal of Experimental Marine Biology and Ecology*, **269**, 197-222.

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.

Brown, J., Gowen, R. & McLusky, D., 1987. The effect of salmon farming on the benthos of a Scottish sea loch. *Journal of Experimental Marine Biology and Ecology*, **109** (1), 39-51.

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.]

Bulnheim, H.P., 1984. Physiological responses of various *Gammarus* species to environmental stress. *Limnologica (Berlin)*, **15**, 461-467.

Cabioch, L., Dauvin, J.C. & Gentil, F., 1978. Preliminary observations on pollution of the sea bed and disturbance of sub-littoral communities in northern Brittany by oil from the *Amoco Cadiz*. *Marine Pollution Bulletin*, **9**, 303-307.

Cole, M., Lindeque, P., Fileman, E., Halsband, C., Goodhead, R., Moger, J. & Galloway, T.S., 2013. Microplastic ingestion by zooplankton. *Environmental science & technology*, **47** (12), 6646-6655.

Cole, S., Codling, I.D., Parr, W., Zabel, T., 1999. Guidelines for managing water quality impacts within UK European marine sites [On-line]. *UK Marine SACs Project.* [Cited 26/01/16]. Available from: http://www.ukmarinesac.org.uk/pdfs/water_quality.pdf

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.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B., 2004. The Marine Habitat Classification for Britain and Ireland. Version 04.05. ISBN 1 861 07561 8. In JNCC (2015), *The Marine Habitat Classification for Britain and Ireland Version 15.03.* [2019-07-24]. Joint Nature Conservation Committee, Peterborough. Available from https://mhc.jncc.gov.uk/

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

Delgado, M., De Jonge, V. & Peletier, H., 1991. Effect of sand movement on the growth of benthic diatoms. *Journal of Experimental Marine Biology and Ecology*, **145** (2), 221-231.

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.

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.*

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.

Essink, K., 1999. Ecological effects of dumping of dredged sediments; options for management. *Journal of Coastal Conservation*, **5**, 69-80.

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.

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.

Fish, J.D. & Fish, S., 1978. Observations on an annual migration of *Bathyporeia pelagica* (Amphipoda, Haustoriidae). *Crustaceana*, **35**, 215-221.

Fish, J.D. & Fish, S., 1996. *A student's guide to the seashore.* Cambridge: Cambridge University Press.

Fish, J.D. & Preece, G.S., 1970. The annual reproductive patterns of *Bathyporeia pilosa* and *Bathyporeia pelagica* (Crustacea: Amphipoda). *Journal of the Marine Biological Association of the United Kingdom*, **50**, 475-488.

Fockedey, N., Ghekiere, A., Bruwiere, S., Janssen, C.R. & Vincx, M., 2006. Effect of salinity and temperature on the intra-marsupial development of the brackish water mysid *Neomysis integer* (Crustacea: Mysidacea). *Marine Biology*, **148** (6), 1339-1356.

Fockedey, N., Mees, J., Vangheluwe, M., Verslycke, T., Janssen, C.R. & Vincx, M., 2005. Temperature and salinity effects on post-marsupial growth of *Neomysis integer* (Crustacea: Mysidacea). *Journal of experimental marine biology and ecology*, **326** (1), 27-47.

Furch, K., 1972. The influence of pretreatment with constant and fluctuating temperatures on the heat resistance of *Gammarus salinus* and *Idotea balthica*. *Marine Biology*, **15**, 12-34.

Gamenick, I. & Giere, O., 1997. Ecophysiological studies on the *Capitella capitata* complex: respiration and sulfide exposure. *Bulletin of Marine Science*, **60**, 613.

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**.

Gittenberger, A. & Van Loon, W.M.G.M., 2011. Common Marine Macrozoobenthos Species in the Netherlands, their Characterisitics and Sensitivities to Environmental Pressures. GiMaRIS report no 2011.08. DOI: 10.13140/RG.2.1.3135.7521

Grassle, J.F. & Grassle, J.P., 1974. Opportunistic life histories and genetic systems in marine benthic polychaetes. *Journal of Marine Research*, **32**, 253-284.

Gray, J.S., 1979. Pollution-induced changes in populations. *Philosophical Transactions of the Royal Society of London*, Series B, **286**, 545-561.

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

Hyland, J.L., Hoffman, E.J. & Phelps, D.K., 1985. Differential responses of two nearshore infaunal assemblages to experimental petroleum additions. *Journal of Marine Research*, **43** (2), 365-394.

Jelassi, R., Bohli-Abderrazak, D., Ayari, A. & Nasri-Ammar, K., 2015. Endogenous activity rhythm in *Talitrus saltator*, *Britorchestia brito* (Crustacea, Amphipoda) and *Tylos europaeus* (Crustacea, Isopoda) from Barkoukech Beach (Tabarka, Tunisia). *Biological Rhythm Research*, **46** (6), 873-886.

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/

Jones, M.B., 1973. Influence of salinity and temperature on the toxicity of mercury to marine and brackish water isopods (Crustacea). *Estuarine and Coastal Marine Science*, **1**, 425-431.

Jones, M.B., 1975b. Effects of copper on the survival and osmoregulation in marine and brackish water isopods (Crustacea). In *Proceedings of the 9th European Marine Biological Symposium* (ed. H. Barnes), 419-431. Scotland: University of Aberdeen Press.

Jones, M.L., 1968. On the morphology, feeding and behaviour of *Magelona* sp. *Biological Bulletin of the Marine Laboratory, Woods Hole*, **134**, 272-297.

Junoy, J., Castellanos, C., Vieitez, J.M. & Riera, R., 2013. Seven years of macroinfauna monitoring at Ladeira beach (Corrubedo Bay, NW Spain) after the Prestige oil spill. *Oceanologia*, **55** (2), 393-407.

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.

Khayrallah, N.H., 1977. *Studies on the ecology of* Bathyporeia pilosa *in the Tay Estuary.* , PhD thesis, University of Dundee.

Kinne, O., 1955. *Neomysis vulgaris* Thompson eine autökologisch-biologische studie. *Biologisches Zentralblatt.*, **74**, 160-202.

Klaoudatos, S., Klaoudatos, D., Smith, J., Bogdanos, K. & Papageorgiou, E., 2006. Assessment of site specific benthic impact of floating cage farming in the eastern Hios island, Eastern Aegean Sea, Greece. *Journal of Experimental Marine Biology and Ecology*, **338** (1), 96-111.

Koepcke, B. & Kausch, H., 1996. Distribution and variability in abundance of *Neomysis integer* and *Mesopodopsis slabberi* (Mysidacea; Crustacea) in relation to environmental factors in the Elbe Estuary. *Archiv fur Hydrobiologie. Supplementband. Untersuchungen des Elbe-Aestuars. Stuggart*, **110**, 263-282.

Kotta, J., Orav-Kotta, H., Herkuel, K. & Kotta, I., 2011. Habitat choice of the invasive *Gammarus tigrinus* and the native *Gammarus salinus* indicates weak interspecific competition. In *Boreal Environment Research, Vol. 16*, pp. 64-72, Boreal Environment Research Publishing Board.

Kuhlmann, D., 1984. Effects of temperature, salinity, oxygen and ammonia on the mortality and growth of *Neomysis integer* Leach. *Limnologica*, **15**, 479-485.

Ladle, M., 1975. The Haustoriidae (Amphipoda) of Budle Bay, Northumberland. *Crustaceana*, **28**, 37-47.

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.

Le Moal, Y., 1980. Ecological survey of an intertidal settlement living on a soft substrata in the Aber Benoit and Aber Wrac'h estuaries, after the *Amoco Cadiz* oil spill. Universite de Bretagne Occidentale, Brest (France), 25pp.

Leewis, L., Van Bodegom, P.M., Rozema, J. & Janssen, G.M., 2012. Does beach nourishment have long-term effects on intertidal macroinvertebrate species abundance? *Estuarine, Coastal and Shelf Science*, **113**, 172-181.

Leineweber, P., 1985. The life-cycles of four amphipod species in the Kattegat. *Holarctic Ecology*, **8**, 165-174.

Mauchline, J., 1971. The biology of *Neomysis integer* (Crustacea; Mysidacea). *Journal of the Marine Biological Association of the United Kingdom*, **51**, 347-354.

Mauchline, J., 1980. The biology of Mysids. *Advances in Marine Biology*, **18**, 1-369.

McCall, P.L., 1977. Community patterns and adaptive strategies of the infaunal benthos of Long Island Sound. *Journal of Marine Research*, **35**, 221-266.

McIntyre, A.D., 1977. Effects of pollution on inshore benthos. In *Ecology of marine benthos*, (ed. B.C. Coull), pp. 301-318. Columbia: University of South Carolina Press

Meißner, K., Darr, A. & Rachor, E., 2008. Development of habitat models for *Nephtys* species (Polychaeta: Nephtyidae) in the German Bight (North Sea). *Journal of Sea Research*, **60** (4), 276-291.

MES, 2010. *Marine Macrofauna Genus Trait Handbook*. Marine Ecological Surveys Limited. http://www.genustraithandbook.org.uk/

Mettam, C., 1989. The life cycle of *athyporeia pilosa* Lindström (Amphipoda) in a stressful, low salinity environment. *Scientia Marina*, **53**, 543-550.

Mills, D.J.L., 1998. Liverpool Bay to the Solway (Rhos-on-Sea to the Mull of Galloway)(MNCR Sector 11). In *Marine Nature Conservation Review. Benthic marine ecosystems of Great Britain and the north-east Atlantic*, pp. 315-338.

NBN, 2016. National Biodiversity Network (12/04/2016). https://data.nbn.org.uk/

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

Nicolaisen, W. & Kanneworff, E., 1969. On the burrowing and feeding habits of the amphipods *Bathyporeia pilosa* Lindström and *Bathyporeia sarsi* Watkin. *Ophelia*, **6** (1), 231-250.

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.

Olsgard, F., 1999. Effects of copper contamination on recolonisation of subtidal marine soft sediments - an experimental field study. *Marine Pollution Bulletin*, **38**, 448-462.

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.

Perkins, E.J., 1974. The marine environment. In *Biology of plant litter decomposition, Volume 2*, (ed. C.H. Dickinson & G.J.F. Pugh), pp. 683-721, London: Academic Press.

Petrich, S.M. & Reish, D.J., 1979. Effects of aluminium and nickel on survival and reproduction in polychaetous annelids. *Bulletin of Environmental Contamination and Toxicology*, **23**, 698-702.

Powell, C.E., 1979. Isopods other than cyathura (Arthropoda: Crustacea: Isopoda). In *Pollution ecology of estuarine invertebrates* (ed. C.W. Hart & S.L.H. Fuller), 325-338. New York: Academic Press.

Preece, G.S., 1970. Salinity and survival in *Bathyporeia pilosa* Lindström and *B. pelagica* (Bate). *Journal of Experimental Marine Biology and Ecology*, **5**, 234-245.

Read, P.A., Anderson, K.J., Matthews, J.E., Watson, P.G., Halliday, M.C. & Shiells, G.M., 1983. Effects of pollution on the benthos of the Firth of Forth. *Marine Pollution Bulletin*, **14**, 12-16.

Redman, C.M., 1985. Effect of temperature and salinity on the life history of *Capitella capitata* (type I). *Dissertation Abstracts*, **46**, 91.

Reyes-Martínez, M.J., Ruíz-Delgado, M.C., Sánchez-Moyano, J.E. & García-García, F.J., 2015. Response of intertidal sandy-beach macrofauna to human trampling: An urban vs. natural beach system approach. *Marine Environmental Research*, **103**, 36-45.

Salvat, B., 1967. La macrofaune carcinologique endogeé des sédiments meubles intertideaux (Tanaidacés, Isopodes et Amphipodes), éthologie, biomie et cycle biologique. *Memoires du Muséum National d' Histoire Naturelle, Paris*, **45** (A), 139-163.

Sandberg, E., 1997. Does oxygen deficiency modify the functional response of *Saduria entomon* (Isopoda) to *Bathyporeia pilosa* (Amphipoda)? *Marine Biology*, **129** (3), 499-504.

Sanders, H.L., 1978. Florida oil spill impact on the Buzzards Bay benthic fauna: West Falmouth. *Journal of the Fisheries Board of Canada*, **35** (5), 717-730.

Setälä, O., Fleming-Lehtinen, V. & Lehtiniemi, M., 2014. Ingestion and transfer of microplastics in the planktonic food web. *Environmental pollution*, **185**, 77-83.

Shull, D.H., 1997. Mechanisms of infaunal polychaete dispersal and colonisation in an intertidal sandflat. *Journal of Marine Research*, **55**, 153-179.

Silva, A.C.F., Tavares, P., Shapouri, M., Stigter, T.Y., Monteiro, J.P., Machado, M., Cancela da Fonseca, L. & Ribeiro, L., 2012. Estuarine biodiversity as an indicator of groundwater discharge. *Estuarine Coastal and Shelf Science*, **97**, 38-43.

Skadsheim, A., 1984. Life cycles of *Gammarus oceanicus* and *G. salinus* (Amphipoda) in the Oslofjord, Norway. *Ecography*, **7** (3), 262-270.

Smith, J.E. (ed.), 1968. 'Torrey Canyon'. *Pollution and marine life.* Cambridge: Cambridge University Press.

Southward, A.J., 1982. An ecologist's view of the implications of the observed physiological and biochemical effects of petroleum compounds on marine organisms and ecosystems. *Philosophical Transactions of the Royal Society of London. B*, **297**, 241-255.

Spooner, G.M., 1947. The distribution of *Gammarus* species in estuaries. Part 1. *Journal of the Marine Biological Association of the United Kingdom*, **27**, 1-52.

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.

UKTAG, 2014. UK Technical Advisory Group on the Water Framework Directive [online]. Available from: http://www.wfduk.org

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.

Voigt, M.O.C., 1991. Community structure of the helminth parasite fauna of gammarids (Crustacea: Amphipoda) in Kiel Bay, western Baltic Sea. *Meeresforschung*, **33**, 266-274.

Ward, T.J. & Young, P.C., 1982. Effects of sediment trace metals and particle size on the community structure of epibenthic seagrass fauna near a lead smelter, South Australia. *Marine Ecology Progress Series*, **9**, 136-146.

Warren, L.M., 1977. The ecology of *Capitella capitata* in British waters. *Journal of the Marine Biological Association of the United Kingdom*, **57**, 151-159.

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.

Weston, D.P., 1990. Quantitative examination of macrobenthic community changes along an organic enrichment gradient. *Marine Ecology Progress Series*, **61** (3), 233-244.

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.

Wu, B., Qian, P. & Zhang, S., 1988. Morphology, reproduction, ecology and isoenzyme electrophoresis of *Capitella* complex in Qingdao. *Acta Oceanologica Sinica*, **7** (3), 442-458.