Hesionura elongata and *Protodorvillea kefersteini* in offshore coarse sand

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

Dr Heidi Tillin & Dr Matt Ashley

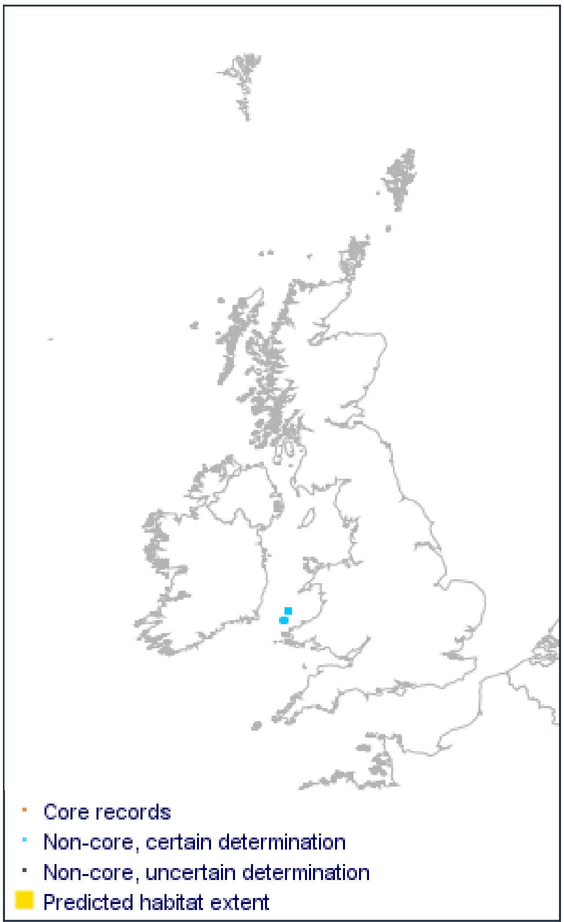
2016-06-29

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

Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [https://www.marlin.ac.uk/habitats/detail/1113]. All terms and the MarESA methodology are outlined on the website (https://www.marlin.ac.uk)

This review can be cited as:
Tillin, H.M. & Ashley, M. 2016. [Hesionura elongata] and [Protodorvillea kefersteini] in offshore coarse 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.1113.1

(page left blank)



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	A5.152	*Hesionura elongata* and *Protodorvillea kefersteini* in offshore coarse sand
JNCC 2015	SS.SCS.OCS.HeloPkef	*Hesionura elongata* and *Protodorvillea kefersteini* in offshore coarse sand
JNCC 2004	SS.SCS.OCS.HeloPkef	*Hesionura elongata* and *Protodorvillea kefersteini* in offshore coarse sand
1997 Biotope		

Description

Offshore (deep) circalittoral habitats with coarse sand may support populations of the interstitial polychaete *Hesionura elongata* with *Protodorvillea kefersteini*. Other notable species include the phyllodocid polychaete *Protomystides limbata* and the bivalve *Moerella pygmaea*. This biotope was reported in the offshore northern North Sea by Eleftheriou and Basford (1989). Relatively little data exists for this biotope (JNCC, 2015).

Depth range

-

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 are taken from JNCC (2015). The biotope occurs in coarse sand habitats that may support populations of the interstitial polychaete *Hesionura elongata* with *Protodorvillea kefersteini.* The sensitivity assessments focus on these characterizing species and the coarse sand habitat. The sensitivity of the bivalve *Moerella pygmaea* (now *Tellina pygmaea*) is considered where information is available. No evidence was found for the polychaete *Protomystides limbata* which is sometimes found in this biotope (JNCC, 2015).

Resilience and recovery rates of habitat

Coarse sediments drain fast, do not retain organic matter, and provide inhospitable conditions for infauna (Gray 1981; Gray *et al.* 1990; Gray & Elliott 2009). Mobile sandbanks and sandwaves occur in dynamic infralittoral environments where sediment is likely to move in tidal cycles and sediment characteristics may change.

The major factor driving the presence of interstitial fauna is likely to be sediment type (Nybakken, 2001). Sediment type and faunal abundance and diversity are intrinsically linked (Basford *et al*., 1990; Seiderer & Newell 1999; Cooper *et al*., 2011), and this is most relevant to interstitial fauna, as these require sediments of a certain grain size that is large enough to enable fauna to inhabit the voids between grains (Nybakken 2001).

Food sources are limited for interstitial fauna characterizing this biotope and availability of food is likely to be an important factor influencing recovery. The characterizing species include active predators and deposit feeding detritivores. Predators, such as *Hesionura elongata*, are known to feed on other interstitial fauna and various infaunal invertebrate species (MES, 2008).

Recovery from pressures such as extraction or abrasion of the substratum may be impeded as interstitial fauna are thought to have limited larval dispersal, as some species keep their eggs and larvae within the sediments (Nybakken 2001). Interstitial fauna are not typically as fecund as infaunal taxa (Nybakken 2001). Small body size and limited mobility of the characterizing species also makes them more susceptible to impacts from removal of sediment, smothering or damage from abrasion. The recovery of interstitial fauna was reported to take years after sediment was removed, or the sediment characteristics altered by deposition.

Protodorvillea is a small free-living polychaete worm belonging to the Family Dorvilleidae. It reaches 1-3 cm in body length and lives in a soft mucous tube under stones, in empty serpulid tubes and in shallow burrows under the surface of muddy sand. It is a carnivore that feeds on small invertebrates at the sediment surface (MES, 2010). It has limited mobility (MES, 2010). The lifespan of this genus is about 1 year and sexual maturity is at about 4-6 months. There is little information on the breeding season or fecundity. After fertilisation, the embryos are brooded before release as planktotrophic larvae and juveniles. The short lifespan, relatively rapid growth rate and larval dispersal phase suggests that this genus has a high recoverability (MES, 2010).

Sardá *et al.* (1999) tracked annual cycles within a *Spisula* community in Bay of Blanes (north west Mediterranean sea, Spain) for 4 years. *Protodorvillea kefersteini* exhibited Spring recruitment and the population persisted throughout the year. Following dredging of subtidal sands in Summer and Autumn to provide material for beach nourishment in the Bay of Blanes, (north west

Mediterranean sea, Spain) recovery was tracked by Sardá *et al.* (2000). Recolonization in the dredged habitats was rapid, for some bivalve and polychaete species but *Protodorvillea kefersteini* had not recovered within two years (Sardá *et al*., 2000). No evidence for recovery rates was found for the characterizing *Moerella* (now *Tellina*) spp., these are a relatively long-lived genus (6-10 years; MES, 2008, 2010) and the number of eggs is likely to be fewer than genera that have planktotrophic larvae.

Where impacts also alter the sedimentary habitat, recovery of the biotope will also depend on recovery of the habitat to the former condition to support the characteristic biological assemblage. Recovery of sediments will be site-specific and will be influenced by currents, wave action and sediment availability (Desprez, 2000). Except in areas of mobile sands, the process tends to be slow (Kenny & Rees, 1996; Desprez, 2000 and references therein). Boyd *et al*., (2005) found that in a site where sands and gravels were subject to long-term extraction (25 years), extraction scars were still visible after six years and sediment characteristics were still altered in comparison with reference areas, with ongoing effects on the biota.

Resilience assessment. Where resistance is 'None' or 'Low' and an element of habitat recovery is required, resilience is assessed as 'Medium' (2-10 years), based on evidence from aggregate recovery studies in similar habitats including Boyd *et al.* (2005); Where resistance of the characterizing species is 'Low' or 'Medium' and the habitat has not been altered, resilience is assessed as 'High' as it is likely that the biotope would be considered representative and hence recovered after two years although some parameters such as species richness, abundance and biotopes may be altered . Recovery of the seabed from severe physical disturbances that alter sediment character may also take up to 10 years or longer (Le Bot *et al*., 2010), although extraction of gravel may result in more permanent changes and this will delay recovery.

NB: The resilience and the ability to recover from human induced pressures is a combination of the environmental conditions of the site, the frequency (repeated disturbances versus a one-off event) and the intensity of the disturbance. Recovery of impacted populations will always be mediated by stochastic events and processes acting over different scales including, but not limited to, local habitat conditions, further impacts and processes such as larval-supply and recruitment between populations. Full recovery is defined as the return to the state of the habitat that existed prior to impact. This does not necessarily mean that every component species has returned to its prior condition, abundance or extent but that the relevant functional components are present and the habitat is structurally and functionally recognizable as the initial habitat of interest. It should be noted that the recovery rates are only indicative of the recovery potential.

Hydrological Pressures

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

Limited evidence was found on the effect of changes in temperature and resistance is inferred from the characterizing species ranges.

Hesionura elongata occurs in the Canary Islands and Caribbean, which suggests a resistance of higher water temperatures than around UK and Irish seas (Brito *et al*., 2005; Miloslavich *et al*., 2010). *Protodorvillea kefersteini* is found in the North Atlantic to the North Sea and English Channel, Mediterranean and Black Sea (Marine Species Identification Portal).

Sensitivity assessment. This assessment relies on limited evidence and utilises global species distribution records and so confidence is low. As all characterizing species occur in water temperatures greater than they are likely to experience in the UK, biotope resistance and resilience are assessed as '**High**' and the biotope is considered to be **'Not Sensitive'**. There is low confidence associated with this assessment as limited evidence was available.

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

Limited evidence was returned on the effect of changes in temperature and resistance is inferred from the species range. *Hesionura elongata* has been identified in samples from water ranging from 7.3-24°C (OBIS, 2016). *Protodorvillea kefersteini* is found in the North Atlantic to the North Sea and English Channel, Mediterranean and Black Sea (Marine Species Identification Portal).

Sensitivity assessment. Limited evidence was available and this assessment is based on non-peer reviewed literature on species range. A 5°C decrease in temperature for one month period is likely to impact the characterizing species in winter months and therefore resistance is '**Medium'**, resilience is '**High'** and Sensitivity is '**Low**'.

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

The biotope occurs in 'full' salinity conditions. An increase in one MNCR salinity category to hypersaline conditions is likely to cause mortality of characterizing species. Resistance is 'None', Resilience is 'High (following restoration of habitat conditions)' and sensitivity is assessed as 'High'. This assessment is assessed based on distribution and confidence is low.

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

This biotope occurs in full salinity habitats. A change at the pressure benchmark is assessed as a decrease from full to reduced salinity(18-30 ppt)

Degraer *et al*. (2006) report that *Hesionura elongata* was found in greatest abundance outside the near coastal zone (in samples from across the Belgium part of the North Sea). This suggests that the species is likely to occur in greater abundance in habitats with full salinity compared to variable salinity or reduced. Moulaert *et al*. (2008) also found that species communities in which *Hesionura elongata* was an indicator species were only present >16 km from the coast and displayed a positive correlation with increasing salinity.

Sensitivity assessment. Resistance is assessed as 'Medium' as *Hesionura elongata* may decrease in and other characterizing species may decrease in abundance. Resilience is assessed as 'High' and sensitivity is assessed as 'Low'.

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

No information on tidal streams was presented in the biotope description from JNCC (2015). This biotope occurs in clean sands and gravels. Sands are less cohesive than mud sediments and a change in water flow at the pressure benchmark may alter sediment transport patterns within the biotope. Hjulström (1939), concluded that fine sand (particle diameter of 0.3-0.6 mm) was easiest to erode and required a mean velocity of 0.2 m/s. Erosion and deposition of particles greater than 0.5 mm require a velocity > 0.2 m/s to alter the habitat. The topography of this habitat is shaped by currents and wave action that influence the formation of ripples in the sediment. Specific fauna may be associated with troughs and crests of these bedforms which may form following an increase in water flow, or disappear following a reduction in flow.

Sensitivity assessment. This biotope probably occurs in areas subject to moderately strong water flows that are a key factor maintaining the clean sand habitat. Changes in water flow may alter the topography of the habitat and may cause some shifts in abundance. However, a change at the pressure benchmark (increase or decrease) is unlikely to affect biotopes that occur in mid-range flows and biotope sensitivity is therefore assessed as 'High' and resilience is assessed as 'High' so that the biotope is considered to be 'Not sensitive'.

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

This biotope does not occur in the intertidal, and consequently an increase in emergence is considered not relevant to this biotope.

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

As this biotope occurs in infralittoral habitats it is not directly exposed to the action of breaking waves. Associated polychaete species that burrow are protected within the sediment but bivalves would be exposed to oscillatory water flows at the seabed. They and other associated species may be indirectly affected by changes in water movement where these impact the supply of food or larvae or other processes. No specific evidence was found to assess this pressure.

Sensitivity assessment. The abundance of characterizing species is likely to be unaffected or increase in areas where fine sediment is removed and coarse sediment is present. However, abundance is likely to decrease in areas where fine sediment is deposited. Under the pressure benchmark levels which consider <5% change, Resistance is assessed as 'High' and resilience as 'High' and the biotope is assessed as '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.

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. The 1969 West Falmouth Spill of Grade 2 diesel fuel, documented by Sanders (1978), illustrates the effects of hydrocarbons in a sheltered habitat with a soft mud/sand substrata (Suchanek, 1993). The entire benthic fauna was eradicated immediately following the spill and remobilization of oil that continued for a period >1 year after the spill contributed to much greater impact upon the habitat than that caused by the initial spill. Effects are likely to be prolonged as hydrocarbons incorporated within the sediment by bioturbation will remain for a long time, owing to slow degradation under anoxic conditions. Oil covering the surface and within the sediment would prevent oxygen transport to the infauna and promote anoxia as the infauna utilise oxygen during respiration. Although this study investigates impacts on an estuarine biotope the impact on benthic infauna communities is likely to be similar in shallow sandbank biotopes.

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

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

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

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

This pressure is **Not assessed**.

Some, all be it limited evidence was returned by searches on activated carbon (AC). AC is utilised in some instances to effectively remove organic substances from aquatic and sediment matrices. Lillicrap *et al.* (2015) demonstrate that AC may have physical effects on benthic dwelling organisms at environmentally relevant concentrations at remediated sites.

De-oxygenation	Medium Q: Low A: Low C: Low	High Q: Low A: Low C: Low	Low Q: Low A: Low C: Low

Limited evidence was returned on effects of decreased dissolved oxygen concentrations on the characterizing species.

All meiofauna have some sensitivity to extended hypoxia, although more mobile nematode species are able to emigrate into the water column in high numbers where they survive (Wetzel *et al.*, 2013). Emigration is likely to increase predation risk. Although evidence on characterizing species is lacking, densities of meiofauna populations are likely to be lower under prolonged anoxia (Moodley *et al.*, 1997).

A turbellarian, *Macrostomum lignano* was found to be a species that is tolerant of a wide range of oxygen concentrations (being able to maintain aerobic metabolism from extremely low P-O2 up to hyperoxic conditions), and is thought to be resistant to the drastic environmental oxygen variations that occur within intertidal sediments (Rivera-Ingraham *et al.*, 2013).

As the biotope occurs in high energy areas strong water flow occurs and deoxygenation is likely to be short lived.

Sensitivity assessment. Due to the limited evidence confidence in this assessment is low. A reduction in meiofauna populations is likely if deoxygenation persisted for long periods, but this is unlikely due to high water flow. As some species are likely to emigrate or maintain aerobic metabolism under low dissolved oxygen conditions, Resistance is assessed as '**Medium**', Resilience is '**High**' and Sensitivity is assessed as '**Low**'.

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

Meiofauna respond to nutrient enrichment. The distribution of different meiofauna assemblages has been identified as a good tool for detecting short-term responses of the benthic domain to nutrient enrichment from sources such as river discharge (Semprucci *et al.*, 2015). In the Bay of Cadiz, Spain, abundance of meiofauna was seven times higher in the presence of macroalgae (Bohorquez *et al.*, 2013).

Sensitivity assessment. As the benchmark levels comply with WFD criteria for good status, Resistance is '**High'**, Resilience is '**High**' and the biotope is '**Not sensitive**' at the benchmark level.

Organic enrichment	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

Protodorvillea kefersteini was identified as a 'progressive' species, i.e. one that shows increased abundance under slight organic enrichment (Leppakoski, 1975, cited in Gray, 1979; Hiscock *et al.*, 2004). *Protodorvillea kefersteini* can become very plentiful in organically enriched habitats (Warwick *et al.*, 1986), this species was very abundant in the vicinity of a sewage outfall at Kircaldy (S.C. Hull pers. comm). *Protodorvillea kefersteini* were dominant species in muddy, organically enriched sediments (organic content approximately 25%) located about 100 and 500 m from fish farm cages, in a bay in Corsica, France (Terlizzi *et al.*, 2010). Similarly, this species was also dominant in sediments close to fish farms in Greek bays where organic matter and nitrogen content had increased.

Sensitivity assessment. *Protodorvillea kefersteini* is tolerant of organic enrichment. At the pressure benchmark organic inputs are considered likely to represent a food subsidy 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 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 infralittoral sand banks and sand waves and other areas of mobile medium-coarse sand, and characterizing species burrow or live interstitially within the sediment and would not be able to survive if the substratum type was changed to either a soft rock or hard artificial type. Consequently, the biotope would be lost altogether if such a change occurred.

Sensitivity assessment. The Resistance to this change is **'**None', and the Resilience is assessed as 'Very low', due to the long-term nature of a change in substratum. The biotope is assessed to have a '**High**' Sensitivity to this pressure at the benchmark.

	Resistance	Resilience	Sensitivity
Physical change (to another sediment type)	Low Q: High A: Medium C: Medium	Very Low Q: High A: High C: High	High Q: High A: Medium C: Medium

Increase in gravel content within the Folk classes is unlikely to negatively impact the characterizing species *Hesionura elongata*. Increases in finer sand or silt are likely to reduce abundance of *Hesionura elongata* as this species is found in greater abundance in sediments with larger grain sizes, and decreases in abundance in fine sediments. Moulaert & Hostens (2007) found that higher gravel content and sediment grain size was a key environmental factor determining the presence of *Hesionura elongata.* Desprez (2000) found that a change of habitat to fine sands from coarse sands and gravels (from deposition of screened sand following aggregate extraction) changed the biological communities present. *Tellina pygmaea* and dominated the fine sand community.

Sensitivity assessment. Sediment changes are likely to alter the composition of the biological assemblage leading to biotope reclassification. Biotope resistance is, therefore, assessed as **Low** (as some species may remain), resilience is **Very low** (the pressure is a permanent change) and sensitivity is assessed as **High**.

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

A number of studies assess the impacts of aggregate extraction on sand and gravel habitats. Extraction would remove the infauna that may be present in this biotope. Recovery of sediments will be site-specific and will be influenced by currents, wave action and sediment availability (Desprez, 2000). Except in areas of mobile sands, the process tends to be slow (Kenny & Rees, 1996; Desprez, 2000 and references therein). Boyd *et al.*, (2005) found that in a site subject to long-term extraction (25 years), extraction scars were still visible after six years and sediment characteristics were still altered in comparison with reference areas with ongoing effects on the biota. The strongest currents are unable to transport gravel. A further implication of the formation of these depressions is a local drop in current strength associated with the increased water depth, resulting in deposition of finer sediments than those of the surrounding substrate (Desprez *et al*., 2000 and references therein). See the physical change pressure for assessment

Sensitivity assessment. Resistance is assessed as 'None' as extraction of the sediment swill remove the characterizing and associated species present. Resilience is assessed as 'Medium' as some species may require longer than two years to re-establish (see resilience section) and sediments may need to recover (where exposed layers are different). Biotope sensitivity is therefore assessed as 'Medium'.

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

No evidence. The characterizing species are infaunal and likely to be protected from abrasion, although movement of sediments may damage a proportion of the population. Biotope resistance is assessed as 'Medium' and resilience as 'High', so that biotope sensitivity is considered to be '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

Protodorvillea kefersteini is soft-bodied and therefore vulnerable to damage by physical abrasion. However, its environmental position as burrowing interstitial species should provide a high degree of protection from activities that lead to surface abrasion only. Similarly, as a small polychaete species, living infaunally and capable of burrowing rapidly, *Hesionura elongata* is also likely to withstand physical disturbance caused by bottom towed fishing gears (such as otter or beam trawls) (Vanosmael *et al*., 1982; Bolam *et al*., 2014). Experiments in shallow, wave disturbed areas, using a toothed, clam dredge, found that some polychaete taxa without external protection and with a carnivorous feeding mode were enhanced by fishing. *Protodorvillea kefersteini* was one of these: large increases in abundance in samples were detected post dredging and persisting over 90 days. The passage of the dredge across the sediment floor will have killed or injured some organisms that will then be exposed to potential predators/scavengers (Frid *et al*., 2000; Veale *et al*., 2000) providing a food source to mobile scavengers including these species.

In a coarse gravelly substratum exposed to high current velocities the crab *Cancer pagurus* was observed to dig pits, approximately 30 cm in diameter and 10 cm deep. Experiments were conducted to identify macrobenthic recolonization processes and differences in abundance between pits and unmanipulated areas.*Protodorvillia kefersteini* (McIntosh) (Polychaeta) showed a rapid increase in abundance at 21 days after disturbance (Thrush, 1986).

Gilkinson *et al*. (1998) simulated the physical interaction of otter trawl doors with the seabed in a laboratory test tank using a full-scale otter trawl door model. Between 58% and 70% of the bivalves in the scour path that were originally buried were completely or partially exposed at the test bed surface. However, only two out of a total of 42 specimens showed major damage. The pressure wave associated with the otter door pushes small bivalves out of the way without damaging them. Where species can rapidly burrow and reposition (typically within species occurring in unstable habitats) before predation mortality rates will be relatively low. These experimental observations are supported by diver observations of fauna dislodged by a hydraulic dredge used to catch *Ensis* spp. Small bivalves were found in the trawl tracks that had been dislodged, from the sediments, including the venerid bivalves *Dosinia exoleta*, *Chamelea striatula* and the hatchet shell *Lucinoma borealis*. These were usually intact (Hauton *et al*., 2003) and could potentially reburrow. *Tellina* (formerly *Moerella pygmaea*) may, therefore, be displaced by penetration and disturbance but survive.

Sensitivity assessment. Evidence is limited but the biological assemblage present in this biotope is characterized by species that are likely to be relatively tolerant of penetration and disturbance of the sediments. Either species are robust or buried within sediments or are adapted to habitats with frequent disturbance (natural or anthropogenic) and recover quickly. Biotope resistance is assessed as ‘Medium’ as some species will be displaced and may be predated or injured and killed. Biotope resilience is assessed as ‘High’ as most species will recover rapidly. Biotope sensitivity is therefore assessed as ‘Low’.

Changes in suspended solids (water clarity)	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 direct evidence was found to assess this pressure, the characterizing polychaetes live infaunally and are predatory and may not be directly impacted by either a decrease or increase in suspended solids.

Sensitivity assessment. Based on the characterizing polychaetes biotope resistance is assessed as

'High' and resilience as 'High' so that the biotope is assessed as 'Not sensitive'.

Smothering and siltation rate changes (light)	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.

Smothering and siltation rate changes (heavy)	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.

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

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

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

Studies of sediment dwelling, sub surface deposit feeding worms, a trait shared by species abundant in this biotope, showed negative impacts from ingestion of micro plastics. For instance, *Arenicola marina* ingests micro plastics that are present within the sediment it feeds within. Wright *et al.* (2013) carried out a lab study that displayed presence of micro plastics (5% UPVC) significantly reduced feeding activity when compared to concentrations of 1% UPVC and controls. As a result, *Arenicola marina* showed significantly decreased energy reserves (by 50%), took longer to digest food, and decreased bioturbation levels. These effects would be likely to impact colonisation of sediment by other species, reducing diversity in the biotopes the species occurs within. Wright *et al.* (2013) also present a case study based on their results, that in the intertidal regions of the Wadden Sea, where *Arenicola marina* is an important ecosystem engineer, *Arenicola marina* could ingest 33m▯; of micro plastics a year.

Sensitivity assessment. '**No evidence**' was returned to complete a sensitivity assessment, however, both microplastics and the toxicants present in cigarette butts are likely to have negative impacts on the characterizing species.

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*., 2012). Electric and magnetic fields smaller than those recorded by in field measurements or modelled results were shown to create increased movement in thornback ray *Raja clavata* and attraction to the source in catshark *Scyliorhinus canicular* (Gill *et al*., 2009).

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

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

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

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

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

All characterizing species live in the sediment and do not rely on light levels directly to feed or find prey so limited direct impact is expected. Most species will respond to the shading caused by the approach of a predator, however, their visual acuity is probably very low. Even then, additional disturbance, such as an electronic flash, caused the retraction of palps and cirri and cessation of all activity for some minutes. Visual disturbance, in the form of direct illumination during the species' active period at night, may therefore result in loss of feeding opportunities, which may compromise growth and reproduction.

As this biotope is not characterized by the presence of primary producers it is not considered that shading would alter the character of the habitat directly. More general changes to the productivity of the biotope may, however, occur. Beneath shading structures there may be changes in microphytobenthos abundance, which would affect food resources (Tait & Dipper, 1998).

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

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

Barrier to species movement	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

This biotope is reported in offshore waters (JNCC, 2015) and this pressure is considered 'Not relevant'.

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

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

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

Characterizing species may have some, limited, visual perception. As they live in the sediment the species will most probably not be impacted at the pressure benchmark.

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

Characterizing species are not cultivated or translocated. This pressure is 'Not relevant'.

Introduction or spread of invasive non-indigenous species	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.

Introduction of microbial pathogens	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence.

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 are targeted directly by fishing activities at a commercial or recreational scale, this pressure is therefore 'Not relevant'.

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

Species within the biotope are not functionally dependent on each other, although biological interactions will play a role in structuring the biological assemblage through predation and competition. Removal of species would also reduce the ecological services provided by these species such as secondary production and nutrient cycling.

Sensitivity assessment. Species within the biotope are relatively sedentary or slow moving although the infaunal position may protect some burrowing species from removal. Biotope resistance is, therefore, assessed as 'Low' and resilience as 'High' as the habitat is likely to be directly affected by removal and some species will recolonize rapidly. Therefore, sensitvity is assessed as 'Low'. Some variability in species recruitment, abundance and composition is natural and therefore a return to a recognisable biotope should occur within 2 years. Repeated chronic removal would, however, impact recovery.

Bibliography

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

Alexander, D., Colcombe, A., Chambers, C. & Herbert, R.J.H. 2014. *Conceptual Ecological Modelling of Shallow Sublittoral Coarse Sediment Habitats to Inform Indicator Selection*. Marine Ecological Surveys Ltd - A report for the Joint Nature Conservation Committee, JNCC Report No: 520

Allen, P.L. & Moore, J.J. 1987. Invertebrate macrofauna as potential indicators of sandy beach instability. *Estuarine, Coastal and Shelf Science*, **24**, 109-125.

Alves, S.N. & De Melo, A.L., 2013. Effects of benzodiazepine and ivermectin on *Girardia tigrina* (Platyhelminthes: Turbellaria). *Bioscience Journal*, **29** (1), 209-215.

Ax, P., 1993. *Promesostoma* species (Platyhelminthes, Rhabdocoela) from Greenland. *Microfauna Marina*, **8**, 153-162.

Ax, P. & Armonies, W., 1990. Brackish water Plathelminthes from Alaska as evidence for the existence of a boreal brackish water community with circumpolar distribution. *Microfauna Marina*, **6**, 7-109.

Bamber, R.N., 1993. Changes in the infauna of a sandy beach. *Journal of Experimental Marine Biology and Ecology*, **172**, 93-107.

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

Bianchelli, S., Pusceddu, A., Buschi, E. & Danovaro, R., 2016. Trophic status and meiofauna biodiversity in the Northern Adriatic Sea: Insights for the assessment of good environmental status. *Marine Environmental Research*, **113**, 18-30.

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

Bohorquez, J., Papaspyrou, S., Yufera, M., van Bergeijk, S.A., Garcia-Robledo, E., Jimenez-Arias, J.L., Bright, M. & Corzo, A., 2013. Effects of green macroalgal blooms on the meiofauna community structure in the Bay of Cadiz. *Marine Pollution Bulletin*, **70** (1-2), 10-17.

Bolam, S.G., Coggan, R.C., Eggleton, J., Diesing, M. & Stephens, D., 2014. Sensitivity of macrobenthic secondary production to trawling in the English sector of the Greater North Sea: A biological trait approach. *Journal of Sea Research*, **85**, 162-177.

Boyd, S., Limpenny, D., Rees, H. & Cooper, K., 2005. The effects of marine sand and gravel extraction on the macrobenthos at a commercial dredging site (results 6 years post-dredging). *ICES Journal of Marine Science: Journal du Conseil*, **62** (2), 145-162.

Brito, M.C., Martin, D. & Nunez, J., 2005. Polychaetes associated to a *Cymodocea nodosa* meadow in the Canary Islands: assemblage structure, temporal variability and vertical distribution compared to other Mediterranean seagrass meadows. *Marine Biology*, **146** (3), 467-481.

Carvalho, S., Moura, A., Gaspar, M.B., Pereira, P., da Fonseca, L.C., Falcao, M., Drago, T., Leitao, F. & Regala, J., 2005. Spatial and inter-annual variability of the macrobenthic communities within a coastal lagoon (Obidos lagoon) and its relationship with environmental parameters. *Acta Oecologica-International Journal of Ecology*, **27** (3), 143-159.

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

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/

Davies, C.E. & Moss, D., 1998. European Union Nature Information System (EUNIS) Habitat Classification. *Report to European Topic Centre on Nature Conservation from the Institute of Terrestrial Ecology, Monks Wood, Cambridgeshire.* [Final draft with further revisions to marine habitats.], Brussels: European Environment Agency.

Degraer, S., Mouton, I., De Neve, L. & Vincx, M., 1999. Community structure and intertidal zonation of the macrobenthos on a macrotidal, ultra-dissipative sandy beach: summer-winter comparison. *Estuaries*, **22**, 742-752.

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

Delamare-Deboutteville C (1960) *Biologie des eaux souterraines littorales et continentales.* Hermann, Paris, pp 740

Desprez, M., 2000. Physical and biological impact of marine aggregate extraction along the French coast of the Eastern English Channel: short- and long-term post-dredging restoration. *ICES Journal of Marine Science*, **57** (5), 1428-1438.

Desprez, M., Pearce, B. and Le Bot, S., 2010. The biological impact of overflowing sands around a marine aggregate extraction site: Dieppe (eastern English Channel). *ICES Journal of Marine Science: Journal du Conseil*, **67**, 270-277

Di Domenico, M., Lana, P. C. & Garraffoni, A.R.S. 2009. Distribution patterns of interstitial polychaetes in sandy beaches of southern Brazil. *Marine Ecology*, **30**: 47-62.

Di Domenico, M., Martínez, A., Lana, d.P.C. & Worsaae, K., 2013. Protodrilus (Protodrilidae, Annelida) from the southern and southeastern Brazilian coasts. *Helgoland Marine Research*, **67** (4), 733-748.

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.*

Eltringham, S.K., 1971. *Life in mud and sand*. London: The English Universities Press Ltd.

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

Faubel, A., Hartig, E. & Thiel, H., 1983. On the ecology of the benthos of sublittoral sediments, Fladen Ground, North Sea. 1. Meiofauna standing stock and estimation of production. *Meteor Forschungsergebnisse*, **36**, 35-48.

Frid, C.L.J., Clark, R.A. 2000. Long term changes in North Sea benthos: discerning the role of fisheries. In: Kaiser MJ and de Groot SJ ed(s). *Effects of fishing on non-target species and habitats*. Oxford, Blackwells Scientific.

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

Giere O (2009) *Meiobenthology. The microscopic motile fauna of aquatic sediments*. Springer, Berlin 528

Gilkinson, K., Paulin, M., Hurley, S. & Schwinghamer, P., 1998. Impacts of trawl door scouring on infaunal bivalves: results of a physical trawl door model/dense sand interaction. *Journal of Experimental Marine Biology and Ecology*, **224** (2), 291-312.

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)

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

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

Hauton, C., Hall-Spencer, J.M. & Moore, P.G., 2003. An experimental study of the ecological impacts of hydraulic bivalve dredging on maerl. *ICES Journal of Marine Science*, **60**, 381-392.

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

Hiscock, K., Southward, A., Tittley, I. & Hawkins, S., 2004. Effects of changing temperature on benthic marine life in Britain and Ireland. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **14** (4), 333-362.

Hjulström, F., 1939. Transportation of detritus by moving water: Part 1. Transportation. Recent Marine Sediments, a Symposium (ed. P.D. Trask), pp. 5-31. Dover Publications, Inc.

Huys, R., Vincx, M., Herman, R., and Heip, C. 1984. *Het meiobenthos vande dumpingszone van titaandioxide-afual in de Nederlandre kustwateren*. Report of the Marine Biology Section, State University of Gent. 102pp

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/

Jouin, C., 1970 *Archiannélides interstitielles de Nouvelle-Calédonie. Expédition Française sur les récifs coralliens de la Nouvelle-Calédonie, 1960–1963*. Ed. de la Fondation Singer-Polignac **4**,147–167.

Kaiser, M., Clarke, K., Hinz, H., Austen, M., Somerfield, P. & Karakassis, I., 2006. Global analysis of response and recovery of benthic biota to fishing. *Marine Ecology Progress Series*, **311**, 1-14.

Kenny, A.J. & Rees, H.L., 1996. The effects of marine gravel extraction on the macrobenthos: results 2 years post-dredging. *Marine Pollution Bulletin*, **32** (8-9), 615-622.

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 Bot, S., Lafite, R., Fournier, M., Baltzer, A. and Desprez, M., 2010. Morphological and sedimentary impacts and recovery on a mixed sandy to pebbly seabed exposed to marine aggregate extraction (Eastern English Channel, France). *Estuarine, Coastal and Shelf Science*, **89**, 221-233.

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.

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

Lin, H.-J., Hsu, C.-B., Liao, S.-H., Chen, C.-P. & Hsieh, H.-L., 2015. Effects of *Spartina alterniflora* invasion on the abundance and community of meiofauna in a subtropical wetland. *Wetlands*, **35** (3), 547-556.

Mackie, A.S.Y., James, J.W.C., Rees, E.I.S., Darbyshire, T., Philpott, S.L., Mortimer, K., Jenkins, G.O. & Morando, A., 2006. Biomôr 4. The outer Bristol Channel marine habitat study. , Cardiff: National Museum Wales.

Martens, P.M. & Schockaert, E.R., 1986. The importance of Turbellarians in the marine meiobenthos - a review. *Hydrobiologia*, **132**, 295-303.

McAllen, R., Walker, D. & Taylor, A., 2002. The environmental effects of salinity and temperature on the oxygen consumption and total body osmolality of the marine flatworm *Procerodes littoralis*. *Journal of Experimental Marine Biology and Ecology*, **268** (1), 103-113.

McLachlan A (1985) The biomass of macro- and interstitial fauna on clean and wrack-covered beaches in Western Australia. *Estuar Coast Shelf Sci* **21** (4):587–599

McLachlan A (1988) *Behavioural adaptations of sandy beach organisms: an ecological perspective.* In: Chelazzi G, Vannini M (eds) *Behavioral adaptation to intertidal life: proceedings of a NATO advanced research workshop on behavioral adaptation to intertidal life, vol 151*., NATA ASI Series A Life SciCastiglioncello, Italy, pp 449–475

McLachlan, A. (1990). Dissipative beaches and macrofaunal communities on exposed intertidal sands. *Journal of Coastal Research* **6**, 57–71

McLachlan, A., Eliot, I.G. & Clarke, D.J., 1985. Water filtration through reflective microtidal beaches and shallow sublittoral sands and its implications for an inshore ecosystem in Western Australia. Estuarine, *Coastal and Shelf Science*, **21** (1), 91-104.

Meire, P.M., Seys, J., Buijs, J. & Coosen, J., 1994. Spatial and temporal patterns of intertidal macrobenthic populations in the Oosterschelde: are they influenced by the construction of the storm-surge barrier? *Hydrobiologia*, **282-283**, 157-182.

Marine Ecological Surveys Limited (MES), 2008. *Marine Macrofauna Genus Trait Handbook*. Marine Ecological Surveys Limited: Bath.

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

Miloslavich, P., Manuel Diaz, J., Klein, E., Jose Alvarado, J., Diaz, C., Gobin, J., Escobar-Briones, E., Jose Cruz-Motta, J., Weil, E., Cortes, J., Carolina Bastidas, A., Robertson, R., Zapata, F., Martin, A., Castillo, J., Kazandjian, A. & Ortiz, M., 2010. Marine Biodiversity in the Caribbean: Regional Estimates and Distribution Patterns. *Plos One*, **5** (8).

Moodley, L., Van Der Zwaan, G.J., Herman, P.M.J., Kempers, L. & Van Breugel, P., 1997. Differential response of benthic meiofauna to anoxia with special reference to Foraminifera (Protista: Sarcodina). *Marine Ecology Progress Series*, **158**, 151-163.

Moulaert, I. & Hostens, K., 2007. Post-extraction evolution of a macrobenthic community on the intensively extracted Kwintebank site in the Belgian part of the North Sea. *CM Documents-ICES*, (A:12).

Moulaert, I., Hostens, K., Hillewaert, H. & Wittoeck, J., 2008. Spatial variation of the macrobenthos species and communities of the Belgian Continental Shelf and the relation to environmental variation. *ICES Document CM 2007/A*, 13 pp.

Murina, G.V., 1981. Notes on the biology of some psammophila Turbellaria of the Black Sea. *Hydrobiologia*, **84** (Oct), 129-130.

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.

Nybakken, J.W. 2001. *Marine Biology, An Ecological Approach*. Fifth editionn. Benjamin Cummings, San Francisco, 516 pp

OBIS, 2016. Ocean Biogeographic Information System (OBIS). http://www.iobis.org, 2016-03-15

Rivera-Ingraham, G.A., Bickmeyer, U. & Abele, D., 2013. The physiological response of the marine platyhelminth *Macrostomum lignano* to different environmental oxygen concentrations. *Journal of Experimental Biology*, **216** (14), 2741-2751.

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

Sardá, R., Pinedo, S. & Martin, D., 1999. *Seasonal dynamics of macroinfaunal key species inhabiting shallow soft-bottoms in the Bay of Blanes (NW Mediterranean).* Publications Elsevier: Paris.

Sardá, R., Pinedo, S., Gremare, A. & Taboada, S., 2000. Changes in the dynamics of shallow sandy-bottom assemblages due to sand extraction in the Catalan Western Mediterranean Sea. *ICES Journal of Marine Science*, **57** (5), 1446-1453.

Seiderer, L.J. & Newell, R.C., 1999. Analysis of the relationship between sediment composition and benthic community structure in coastal deposits: Implications for marine aggregate dredging. *ICES Journal of Marine Science*, **56**, 757-765.

Semprucci, F., Frontalini, F., Sbrocca, C., du Chatelet, E.A., Bout-Roumazeilles, V., Coccioni, R. & Balsamo, M., 2015. Meiobenthos and free-living nematodes as tools for biomonitoring environments affected by riverine impact. *Environmental Monitoring and Assessment*, **187** (5), 1-19.

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.

Terlizzi, A., De Falco, G., Felline, S., Fiorentino, D., Gambi, M.C. and Cancemi, G., 2010. Effects of marine cage aquaculture on macrofauna assemblages associated with Posidonia oceanica meadows. *Italian Journal of Zoology*, **77**,362-371.

Thrush, S.F., 1986. Community structure on the floor of a sea-lough: are large epibenthic predators important? *Journal of Experimental Marine Biology and Ecology*, **104**, 171-183.

Urban-Malinga, B., Warzocha, J. & Zalewski, M., 2013. Effects of the invasive polychaete *Marenzelleria* spp. on benthic processes and meiobenthos of a species-poor brackish system. *Journal of Sea Research*, **80**, 25-34.

Vanaverbeke, J., Bellec, V., Bonne, W., Deprez, T., Hostens, K., Moulaert, I., Van Lancker, V. & Vincx, M., 2007. Study of post-extraction ecological effects in the Kwintebank sand dredging area (SPEEK). Final report. *Scientific Support Plan for a Sustainable Development Policy*, *SPSDII. Part 2 Global Change, Ecosystems and Biodiversity*, *Belgian Science Policy*, *Brussels*, 91 pp.

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.

Vanosmael, C., Willems, K.A., Claeys, D., Vincx, M. & Heip, C., 1982. Macrobenthos of a sublittoral sandbank in the southern bight of the North Sea. *Journal of the Marine Biological Association of the United Kingdom*, **62**, 521-534.

Veale, L.O., Hill, A.S., Hawkins, S.J. & Brand, A.R., 2000. Effects of long term physical disturbance by scallop fishing on subtidal epifaunal assemblages and habitats. *Marine Biology*, **137**, 325-337.

Vezzulli, L., Pezzati, E., Moreno, M., Fabiano, M., Pane, L., Pruzzo, C. & VibrioSea, C., 2009. Benthic ecology of *Vibrio spp.* and pathogenic *Vibrio* species in a coastal Mediterranean environment (La Spezia Gulf, Italy). *Microbial Ecology*, **58** (4), 808-818.

Von Nordheim, H.,1 89 Comparative ultrastructural investigation of the euspermatozoa and paraspermatozoa of 13 Protodrilus species Polychaeta Annelida and its taxonomical and phylogenetical implications. Helgolaender Meeresuntersuchungen, 43 (2), 113-156.

Warwick, R.M., 1984. The benthic ecology of the Bristol Channel. *Marine Pollution Bulletin*, **15** (2), 70-76.

Wetzel, M.A., Fleeger, J.W. & Powers, S.P., 2013. Effects of hypoxia and anoxia on meiofauna: A review with new data from the Gulf of Mexico. *Coastal Hypoxia: Consequences for Living Resources and Ecosystems*: American Geophysical Union, pp. 165-184.

Willems, K.A., Vanosmael, C., Claeys, D., Vincx, M. & Heip, C., 1982. Benthos of a sublittoral sandbank in the southern bight of the North Sea: general considerations. *Journal of the Marine Biological Association of the United Kingdom*, **62**, 549-557.

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.

Witt, J., 2004. *Analysing brackish benthic communities of the Weser estuary: Spatial distribution, variability and sensitivity of estuarine invertebrates.*Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven,

Wright, E.P., Kemp, K., Rogers, A.D. & Yesson, C., 2015. Genetic structure of the tall sea pen *Funiculina quadrangularis* in NW Scottish sea lochs. *Marine Ecology*, **36** (3), 659-667.

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

Zettler M.L., Proffitt, C.E., Darr, A., Degraer, S., Devriese, L., Greathead, C., Kotta, J., Magni, P., Martin, G., Reiss, H., Speybroeck, J., Tagliapietra, D., Van Hoey, G. & Ysebaert, T., 2013. On the myths of indicator species issues and further consideration in the use of static concepts for ecological applications. *Plos One*, **8** (10), e78219.