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Nephtys cirrosa and *Bathyporeia* spp. in infralittoral sand

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

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Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [https://www.marlin.ac.uk/habitats/detail/154]. All terms and the MarESA methodology are outlined on the website (https://www.marlin.ac.uk)

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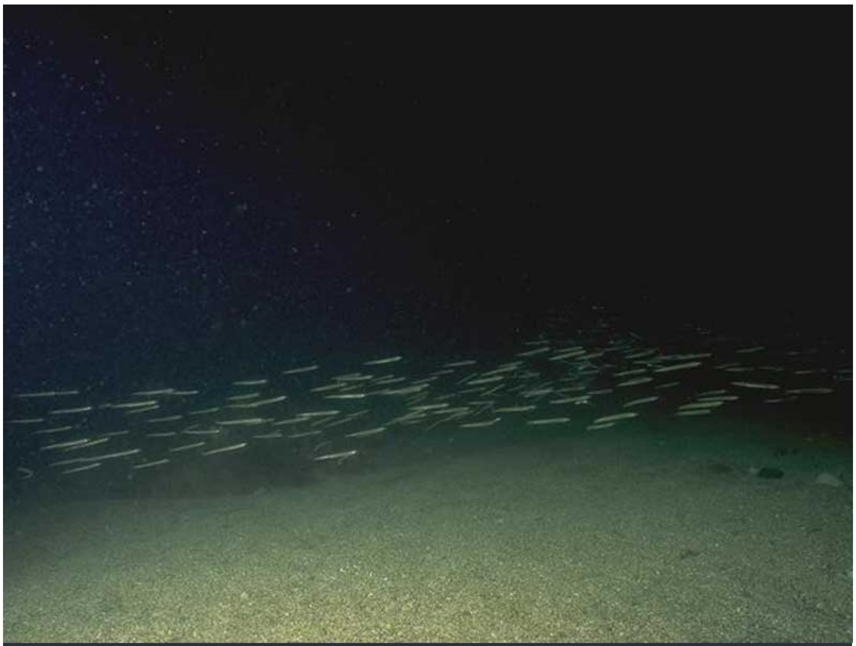
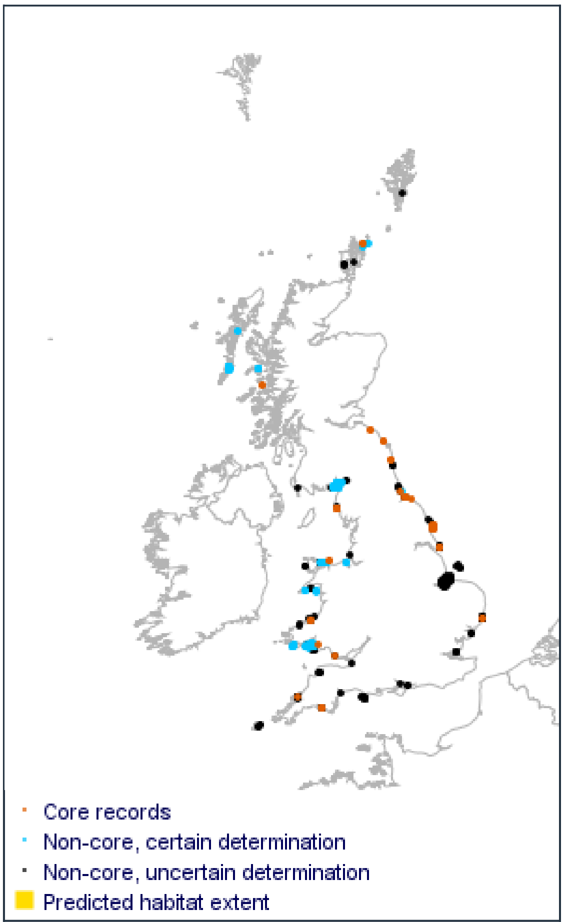


Sand eel shoal over sandy seabed.
Photographer: Francis Bunker



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

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

Summary

UK and Ireland classification

EUNIS 2008	A5.233	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand
JNCC 2015	SS.SSa.IFiSa.NcirBat	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand
JNCC 2004	SS.SSa.IFiSa.NcirBat	*Nephtys cirrosa* and *Bathyporeia spp.* in infralittoral sand
1997 Biotope	SS.IGS.FaS.NcirBat	*Nephtys cirrosa* and *Bathyporeia spp.* in infralittoral sand

Description

Well-sorted medium and fine sands characterized by *Nephtys cirrosa* and *Bathyporeia* spp. (and sometimes *Pontocrates* spp.) which occur in the shallow sublittoral to at least 30 m depth. This biotope occurs in sediments subject to physical disturbance, as a result of wave action (and occasionally strong tidal streams). The magelonid polychaete *Magelona mirabilis* may be frequent in this biotope in more sheltered, less tideswept areas whilst in coarser sediments the opportunistic polychaete *Chaetozone setosa* may be commonly found. The faunal diversity of this biotope is considerably reduced compared to less disturbed biotopes (such as FfabMag) and for the most part consists of the more actively-swimming amphipods. Sand eels *Ammodytes* sp. may occasionally be observed in association with this biotope (and others) and spionid polychaetes such as *Spio filicornis* and *Spio martinensis* may also be present. Occasional *Lanice conchilega* may be visible at the sediment surface (JNCC, 2015).

Depth range

0-5 m, 5-10 m

Additional information

No text entered.

Listed By

- none -

Further information sources

Search on:

G G G JNCC

Habitat review

Ecology

Ecological and functional relationships

- Communities in wave exposed sand habitats and, by extension, any sediments subject to hydrodynamic disturbance have been assumed to be primarily controlled by specific species responses to the hydrodynamic climate and sediment characteristics which are intimately linked, a scenario where biological interactions do not appear to play a critical role (McLachlan, 1983). Consequently mean macrobenthic diversity and species richness of clean mobile sands is generally lower than that of the surrounding seabed, reflecting greater stresses inherent in such environments (Elliott *et al.*, 1998).
- Intertidal and subtidal sandy biotopes comprise an unusual ecosystem in that the customary food chain of plants-herbivores-carnivores is not clearly discernible (Eltringham, 1971), the physical environment being too harsh for vegetation to become established. The absence of macroalgae means that herbivorous macrofauna either feed on the biogenic film, on and in the deposit (e.g. *Bathyporeia pelagica* which is an epistrate feeder) or on phytoplankton from the overlying seawater.
- The meiofauna are likely to be important consumers of the microphytobenthic productivity. The dominant components of sandbank meiofauna are nematodes and harpacticoid copepods with several other taxa of variable importance (McLachlan, 1983). There is a well established relationship between the relative proportions of nematodes, harpaticoids and grain size. Nematodes tend to dominate in finer sediments, harpaticoids in coarser sediments and in sediments with a median grain size of 0.3-0.35 mm they are both equally important (Gray, 1971; McLachlan *et al.*, 1981).
- Polychaete worms are dominant infaunal predators, they are opportunistic and actively pursue prey, so that their numbers may be closely related to that of their prey which includes other polychaetes and small crustaceans (Meire *et al.*, 1994). Bamber (1993) found a significant linear correlation between declining densities of *Scoloplos armiger* and increasing densities of *Nephtys cirrosa* in a psammophilous polychaete community from the Solent Coast, Hampshire. *Nephtys* species also scavenge, as does the isopod, *Eurydice pulchra*, which also actively preys upon the amphipod *Bathyporeia pelagica*.
- Conspicuous epibenthic species that may be encountered within the biotope include shrimps (*Crangon crangon*), crabs (*Carcinus maenas*, *Cancer pagurus* and *Pagurus bernhardus*), starfish (*Asterias rubens*). Sand eels, *Ammodytes* sp., may be locally abundant, whilst juvenile gadoids (*Gadus morhua* & *Pollachius virens*), adult and juvenile flatfish (*Pleuronectes platessa*, *Limanda limanda* & *Platichthys flesus*) frequent the biotope to feed upon the epi- and infauna.

Seasonal and longer term change

- A seasonal pattern of abundance is demonstrated by many species, and is characterized by annual recruitment of species increasing their density typically in late summer/autumn. For instance, common cumaceans recorded within the biotope, *Pseudocuma longicornis* and *Cumopsis goodsiri*, are almost entirely restricted in their presence to late summer-autumn months (Bamber, 1993). Two reproductive peaks for *Bathyporeia pelagica* occur in spring and autumn suggesting that an overwintering population matures slowly and reproduces in the spring, and their progeny mature rapidly over five months to reproduce in the autumn of the same year (Watkin, 1939b).

- Warmer summers may cause temporary declines in the abundance of some species as a result of recruitment failure (juveniles being potentially more sensitive). For instance in a sandy shore community following the warm summer of 1989, Bamber (1993) recorded a significant decrease in the *Bathyporeia sarsi* population, a species which shows its southern limit of distribution in the English Channel.
- Mortality of some of the infaunal and epifaunal population may be expected as a result of any winter storms that cause suspension of the substratum.
- Seasonal changes been documented for the meiofauna of sandy shores in temperate regions, with the meiofauna occurring in lower abundance and moving deeper into the sediment in winter (citations in McLachlan, 1983). Vertical migrations other than seasonal have been reported in response to heavy rain, wave disturbance, tidal factors and changes in moisture and oxygen over the tidal cycle.
- Vertical migrations from the substratum into the overlying sea water are made by the dominant crustaceans e.g. *Eurydice pulchra* and *Bathyporeia pelagica* on nearly every night of the year. Such behaviour is endogenously controlled and has a circatidal rhythm that is coupled to a circasemilunar pattern of emergence (Alheit & Naylor, 1976; Jones & Naylor, 1970; Preece, 1971; Fincham, 1970a & 1970b; Watkin, 1939b).

Habitat structure and complexity

Superficially the habitat may appear to be rather homogenous, but within the sand a variety of niches are probably available for colonization. For instance, sandbanks may show a gradient from finer sediments to coarser sediments resulting from the prevailing current pattern. The upper sand layers may be characterized by sand waves and ripples occurring on a variety scales, which are continually destroyed and rebuilt by currents, a process visible at the waters surface by the appearance of patches of suspended sediment. In other instances the distribution of different grades of sandy sediment may be very patchy and at the bottom of depressions finer sediments, more stable deposits, enriched with some mud might be found (Vanosmael *et al.*, 1982).

Productivity

The macrobenthic infauna of the biotope consists of animals which feed largely on particulate matter in or on the sand, and which are themselves preyed upon by populations of juvenile flatfish (McIntyre & Eleftheriou, 1968). Owing to the lack of stable substrata, benthic microalgae constitute the main primary producers of the biotope and the quality of light (as critical depth for primary production) reaching sandbanks in the sublittoral will determine the type of microalgae colonizing the sediment. Owing to turbulence created by tidal flow and wave action, overlying water may be particularly turbid, limiting primary production further. Steele & Baird (1968) estimated microphytobenthic production to be 4-9 g C/m^2/yr a figure they considered to be inadequate for the macrofauna and rich meiofauna (assuming an ecological efficiency of 10%, the infaunal biota of this biotope would probably have an annual requirement in the region of 25 g C/m^2). To support the infauna the biotope must be subsidised to a high degree by organic matter produced in the water column and other environments and transported to the biotope, consequently productivity of this biotope is mostly secondary (McLachlan, 1980). Primary production in the water column was estimated to be in the region of 95 g C/m^2 annually (Steele & Baird, 1968) and some of this is directly available or may reach the benthos indirectly after intervening trophic levels. Baird & Steele (1968) demonstrated that only 3-5% of the organic matter in the sand was unattached, so that a continuous supply of material and rapid filtering of water through the sand are essential if the requirements of the benthos are to be met.

Recruitment processes

Characterizing macrofauna of the biotope are iteroparous, meaning that they breed several times per lifetime. Some species have a brooding and benthic mode of reproduction whilst others are broadcast spawners with a planktonic phase of development.

- Important meiofaunal nematodes and harpacticoid copepods of the sandy shore are reported to have year-round reproduction with generation times ranging from 1-3 months (McIntyre, 1969).
- *Bathyporeia pelagica* may breed throughout the year, but the greatest reproductive activity occurs during spring and late summer/autumn. Males and females pair whilst swimming and mate on the night-time ebb tides following each new and full moon. Development of an egg to the stage when it is released as a juvenile takes just 15 days to complete. The overwintering population of *Bathyporeia pelagica* consists largely of juvenile animals. These mature in spring to form the majority of the next breeding population and eventually die in June and July, after a lifespan of about one year (Fish & Preece, 1970).
- *Eurydice pulchra* breeds between April and August once sea temperatures rise above 10°C, and the highest number of juveniles occur around the periods of maximum summer temperatures. Although the first juveniles may reach sexual maturity before the onset of winter, they begin breeding in the following spring and die during their second autumn after a total lifespan of approximately 15 months. Mid-summer juveniles also mature to breed the following summer and only reached 12 months of age before dying. In contrast, the last broods appearing as late as October, do not mature until late the following summer. They breed in their second October and then overwinter for a second time, producing a second brood in the spring before dying of at 18-20 months old (Hayward, 1994; Jones, 1970; Fish, 1970).
- Polychaete worms such as *Nephtys* spp. and spionid worms release their eggs and sperm into the water where, after fertilization and a relatively prolonged planktonic phase of development, they metamorphose and commence a benthic habit. Recruitment of *Nephtys* species seems related to environmental conditions in central parts of the species range, marginal populations exhibit occasional reproductive failures, e.g. *Nephtys cirrosa*, which is a temperate species and reaches the northern limit of its range in the north of the British Isles. Populations of *Nephtys cirrosa* on the east and west coasts of northern Britain exhibit different reproductive patterns. In south-west Scotland gravid adults breed every year in early autumn, whilst those on the east coast experience periods (e.g. over three years) of reproductive failure (Olive & Morgan, 1991).

Time for community to reach maturity

As a consequence of the dynamic nature of the habitat the faunal component of the biotope is very sparse and low in species richness. Therefore, the community might be considered 'mature' (in terms of representative species present) only a few days or weeks after the last disturbance, as displaced polychaetes and crustaceans re-enter the substratum.

Additional information

No text entered.

Preferences & Distribution

Habitat preferences

Depth Range	0-5 m, 5-10 m
Water clarity preferences	Field Unresearched
Limiting Nutrients	Field unresearched
Salinity preferences	Full (30-40 psu)
Physiographic preferences	Enclosed coast / Embayment, Open coast
Biological zone preferences	Infralittoral
Substratum/habitat preferences	Fine clean sand, Medium clean sand
Tidal strength preferences	Very Weak (negligible), Weak < 1 knot (<0.5 m/sec.)
Wave exposure preferences	Exposed, Moderately exposed
Other preferences	

Additional Information

No text entered.

Species composition

Species found especially in this biotope

- *Bathyporeia spp.*
- *Eurydice pulchra*
- *Haustorius arenarius*
- *Nephtys cirrosa*
- *Pontocrates arenarius*
- *Scoloplos armiger*
- *Spiophanes bombyx*

Rare or scarce species associated with this biotope

-

Additional information

The occurrence of rare species and very high diversity is unusual in mobile sandbanks. However, important species of interstitial polychaete may be recorded within the biotope, for instance, *Polygordius appendiculatus*, which has a preference for coarse and medium sands. In mobile subtidal sandbanks in the North Sea, Vanosmael *et al.*, (1982) found exceptional numbers of Epilonematidae and Draconematoidea (Nematoda) and three important species of interstitial polychaetes, *Polygordius appendiculatus*, *Protodriloides chaetifer* and a species of the genus *Protodrilus*. Such species are adapted to the extreme instability of the substratum of the sandbanks and are confined to such biotopes (Elliott *et al.*, 1998).

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The biotope description and characterizing species are taken from JNCC (2015). This biotope is characterized by mobile clean sand sediments in shallow water The mobility of the sediment leads to a species-poor community, with polychaetes (*Nephtys cirrosa*), and burrowing amphipods (*Bathyporeia* spp. characterizing the biotope. The sediments and wave exposure are key factors maintaining the biotope and are considered in the sensitivity assessments where the pressure may alter these.

Resilience and recovery rates of habitat

The species inhabiting this biotope are characteristic of mobile sediments and are adapted to the high levels of disturbance. The species present in the biotope must either be able to withstand mobile sediments through physical robustness, mobility and ability to re-position within sediments such as *Nephtys cirrosa* and the mobile amphipods and/or to recover rapidly to sustain population losses following severe erosion. Characterizing species typically have opportunistic life history strategies, with short life histories (typically two years or less, see below), rapid maturation and extended reproductive periods. Typically they produce juveniles that are either brooded (amphipods and isopds) and are therefore present to repopulate the disturbed habitat directly, or have pelagic larvae (*Nephtys cirrosa*) capable of dispersal within the water column. Adults may also be transported in the water column.

The amphipods characterizing this biotope are found in sediments subject to physical disturbance, as a result of wave action or in wave sheltered biotopes, strong tidal streams. This group is, therefore, tolerant of disturbed environments and can recover quickly. *Bathyporeia* spp. are short lived, reaching sexual maturity within 6 months with 6-15 eggs per brood, depending on species. Reproduction may be continuous (Speybroeck *et al*., 2008) with one set of embryos developing in the brood pouch whilst the next set of eggs is developing in the ovaries. However, specific reproductive periods vary between species and between locations (Mettam, 1989) and bivoltine patterns (twice yearly peaks in reproduction) have been observed (Mettam, 1989; Speybroeck *et al*., 2008). Adult amphipods are highly mobile in the water column and recolonization by the adults is likely to be a significant recovery pathway. The life history traits of rapid sexual maturation and production of multiple broods annually support rapid local recolonization of disturbed sediments where some of the adult population remains.

Nephtys cirrosa is a relatively long-lived polychaete with a lifespan of 6 to possibly as much as 9 years. It matures at 1 year and the females release over 10,000 (and up to 80,000 depending on species) eggs of 0.11-0.12mm from April through to March. These are fertilized externally and develop into an early lecithotrophic larva & a later planktotrophic larva which spends as much as 12 months in the water column before settling from July-September. The genus has a relatively high reproductive capacity and widespread dispersion during the lengthy larval phase. It is likely to have a high recoverability following disturbance (MES, 2010). Adults are mobile and capable of swimming and adults are therefor qable to migrate in and out of this biotope.

Resilience assessment. As a consequence of the dynamic nature of the habitat the faunal component of the biotope is very sparse and low in species richness. Therefore, the community might be considered 'mature' only a few days or weeks after the last storm event, as the mobile species displaced from the biotope and those from adjacent area colonize the substratum via the surf plankton. Even following severe disturbances recovery would be expected to occur within a year; biotope resilience is therefore assessed as 'High' for any level of impact (e.g. where resistance is 'None', 'Low' or 'Medium').

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

The amphipods that occur within this habitat are mobile and can avoid unfavourable conditions to some extent. *Bathyporeia* life cycles vary between locations and this is related to temperature (Mettam, 1989). Preece (1971) tested temperature tolerances of *Bathyporeia pelagica* and *Bathyporeia pilosa* in the laboratory. Individuals acclimated to 15°C for 24 hours were exposed to temperature increases (water temperature raised by 0.2°C/minute). As test temperature were reached individuals were removed, placed in seawater at 4°C and allowed to recover for 24 hours at which point mortalities were tested. Amphipods were also allowed to bury into sediments and held at test temperatures for 24 hours of 32.5 °C, 31.8°C and 29.5°C before being allowed to recover in fresh seawater at 15°C for a further 24 hours, before mortalities were assessed. Upper lethal temperatures (the temperature at which 50% of individuals died for adult males and gravid females of *Bathyporeia pilosa* were 37.5°C and 39.4°C, respectively. *Bathyporeia pelagica* exhibited lower tolerances and adult males and gravid females had upper lethal temperature tolerances of 33.4 and 34.2°C respectively. These tests measures short-term exposure only and species had lower tolerance for longer-term (24 hour exposure). No mortality occurred for *Bathyporeia pilosa* individuals held at 29.5°C and 30.8°C; however 15% of individuals exposed to water temperatures of 31.8°C and 96% at 32.5°C died. *Bathyporeia pelagica* exhibited lower tolerances, 11% of individuals died after 24 hr exposure to 29.5°C and 100% mortality occurred at 30.8°C and above (Preece, 1971).

Emery & Stevensen (1957) reported that *Nephtys spp.* could withstand summer temperatures of 30-35 °C so is likely to withstand the benchmark acute temperature increase. An acute increase in temperature at the benchmark level may result in physiological stress endured by the infaunal species but is unlikely to lead to mortality.

Sensitivity assessment. Typical surface water temperatures around the UK coast vary seasonally from 4-19 °C (Huthnance, 2010). A chronic increase in temperature throughout the year of 2°C may fall within the normal temperature variation and an acute increase in water temperatures from 19 to 24°C for a month may be tolerated by the characterizing species supported by deeper burrowing and/or migration. For *Bathyporeia* spp. temperature increases above 30°C appear to be critical based on Preece (1971). Biotope resistance is therefore assessed as 'High' and resilience as 'High' so that the biotope is assessed as 'Not sensitive'. Increased water and air temperatures and desiccation may lead to greater synergistic effects and the loss of characterizing amphipods and isopods may result in shifts between the variant sub-biotopes.

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

Crisp (1964) reported that species of amphipod and isopods seemed to be unharmed by the severe winter of 1962-1963. This may be due to burial in sediments buffering temperature or seasonal migration to deeper waters to avoid freezing.

Preece (1971) tested the temperature tolerances of *Bathyporeia pelagica* and *Bathyporeia pilosa* in the laboratory. Individuals acclimated to 15°C for 24 hours were placed in a freezer in wet sediment. As test temperatures were reached individuals were removed and allowed to recover for 24 hours at which point mortalities were tested. Amphipods were also allowed to bury into sediments and held at test temperatures of -1°c, -3°C and -5°C for 24 hours before being allowed to recover in fresh seawater at 15°C for a further 24 hours before mortalities were assessed. Lower lethal short-term tolerances *of Bathyporeia pilosa* and *Bathyporeia pelagica* were -13.6°C and -6.4°C respectively. Sensitivity to longer-term exposure is greater, especially for *Bathyporeia pelagica*. *Bathyporeia pilosa* individuals could withstand temperatures as low as -1°C for 24 hours, while 42% of *Bathyporeia pelagica* died. At -3°C 5% of *Bathyporeia pilosa* died (100% of *Bathyporeia pelagica*) but this rose to 82% at -5°C.

Nephtys cirrosa reaches its northern limit in Scotland, and German Bight of the North Sea. A decrease in temperature is likely to result in loss of the species from the SS.SSa.SSaVS biotope in Scotland.

Sensitivity assessment. Typical surface water temperatures around the UK coast vary seasonally from 4-19 °C (Huthnance, 2010). A chronic decrease in temperature throughout the year of 2°C may fall within the normal temperature variation but an acute decrease in water temperatures from 4°C to -1°C at the coldest part of the year may lead to freezing and lethal effects on for a month may be tolerated by the characterizing species supported by deeper burrowing and/or migration to deeper waters. For *Bathyporeia* spp. seawater temperature decreases below -1°C appear to be critical based on Preece (1971). Biotope resistance is therefore assessed as 'Medium' and resilience as 'High' so that biotope sensitivity is assessed as 'Low'.

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

This biotope is found in full salinity (30-35 ppt) habitats (JNCC, 2015), a change at the pressure benchmark is therefore assessed as a change to hypersaline conditions. Little evidence was found to assess responses to hypersalinity. However, monitoring at a Spanish desalination facility where discharges close to the outfall reached a salinity of 53, found that amphipods were sensitive to the increased salinity and that species free-living in the sediment were most sensitive. The study area did not host any of the species characterizing this biotope but the results indicate a general sensitivity (De-la-Ossa-Carretero, *et al*., 2016).

Sensitivity assessment. Not assessed, 'No evidence'.

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

The biotope is found in full salinity habitats (JNCC, 2015). A change at the pressure benchmark refers to a decrease from full to variable (18-35 ppt), or to reduced salinity (18-30 ppt). *Bathyporeia pelagica* migrates seaward in response to reduced salinities, the effect of which is enhanced by higher temperature (Preece, 1970). *Bathyporeia pilosa* is, however, more tolerant of low salinities and is capable of reproducing at salinities as low as 2 (Khayrallah, 1977). Populations of *Bathyporeia pilosa* within the upper reaches of the Severn Estuary experience wide fluctuations in salinity ranging from 1-22 depending on the season and tidal cycle (Mettam, 1989). The physiological stress for this environment affects size and reproduction (Mettam, 1989). Speybroeck *et al*. (2008) noted that *Bathyporeia pilosa* tends to occur subtidally in estuarine and brackish conditions. Local populations may be acclimated to the prevailing salinity regime and may exhibit different tolerances to other populations subject to different salinity conditions and, therefore, caution should be used when inferring tolerances from populations in different regions.

A reduction in salinity at the pressure benchmark could result in the loss of species or changes in abundance and biotope reversion to the biotope SS.SSa.SSaVS.MoSaVS which occurs in typical mobile sand conditions but in reduced salinities and lacks *Nepthys cirrosa* and *Bathyporeia* spp. (although these may be washed in from adjacent communities) (JNCC, 2015) or a change to SS.SSa.SSaVS.NcirLim, which occurs in variable salinity and contains the bivalve *Limecola balthica*.

Sensitivity assessment. A decrease in salinity is likely to lead to changes in species abundance and richness and may lead to biotope reclassification. Biotope resistance is assessed as 'None' and resilience as 'High' (following restoration of typical habitat conditions). Sensitivity is therefore assessed as 'Medium'.

	Resistance	Resilience	Sensitivity
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

Water movement is a key factor physically structuring this biotope although exposure to wave action may be more significant for many examples than tidal streams. This biotope is recorded where tidal streams are weak (<0.5 m/s)or very weak (negligible) (JNCC, 2015), in areas where flows are lower, wave action may be more important in maintaining the sediment mobility that structures the biotope. Where similar sand habitats occur in more sheltered areas the biological structure alters in response to the increased or decreased sediment mobility with *Magelona mirabilis* found in higher abundances in more sheltered habitats and *Chaetozone setosa* found in more disturbed habitats (JNCC, 2015). An increase in disturbance may lead to biotope reversion to the similar biotope SS.SSa.IFiSa.IMoSa which occurs in more disturbed areas. A decrease in disturbance may lead to changes to SS.SSa.IMuSa.FfabMag, where finer sediments are deposited.

Sensitivity assessment. The sediments that characterize this biotope and sub-biotopes are mobile sands that range from medium to fine, a change at the pressure benchmark (increase or decrease) may lead to some changes in sediment sorting. Based on the range of water flows experienced, biotopes occurring in habitats at the middle of the range are considered to be 'Not sensitive' to an increase or decrease in flow at the pressure benchmark. Changes in water flow in areas sheltered from wave action could. however, lead to changes in biotope classification due to the increase in sediment stability.

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 to sublittoral biotopes.

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

Water movement is a key factor physically structuring this biotope, with sediment sorting and mobilisation by tidal streams and wave action modifying the sediments present and the level of disturbance. The assessed biotope is found in habitats that are exposed to sheltered from wave action (JNCC, 2015).

Sensitivity assessment. Wave action is a key factor structuring this biotope through sediment mobility. As the biotope occurs across two wave exposure categories (JNCC, 2015) this is considered to indicate, by proxy, that a change in wave exposure at the pressure benchmark is less than the natural range of wave heights experienced. Biotope resistance to this pressure is therefore assessed as 'High' and resilience as 'High (by default) so that the biotope is considered to be 'Not sensitive' at the pressure benchmark.

Chemical Pressures

	Resistance	Resilience	Sensitivity
Transition elements & organo-metal contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

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*.

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.

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.

In general, crustaceans are widely reported to be intolerant of synthetic chemicals (Cole *et al.*, 1999) and intolerance 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. 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.

Radionuclide contamination	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence.

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

This pressure is **Not assessed**.

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

Information concerning the reduced oxygen tolerance of *Nephtys cirrosa* was not found but evidence (Alheit, 1978; Arndt & Schiedek, 1997; Fallesen & Jørgensen, 1991) indicated a similar species, *Nephtys hombergii*, to be very tolerant of episodic oxygen deficiency and at the benchmark duration of one week.

Laboratory studies by Khayrallah (1977) on *Bathyporeia pilosa*, indicated that it has a relatively poor resistance to conditions of hypoxia in comparison to other interstitial animals. However, Mettam (1989) and Sandberg (1997) suggest that *Bathyporeia pilosa* can survive short-term hypoxia.

Sensitivity assessment. This biotope is characterized by mobile sands in areas that experience strong water flows or are wave exposed. The mixing effect of wave action and water movement will limit the intensity and duration of exposure to deoxygenated waters. The species characterizing the biotope are also mobile and able to migrate vertically or shorewards 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	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

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 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 sediment mobility). Biotope resistance is therefore assessed as 'High', resilience as 'High' (by default) and the biotope is considered to be 'Not sensitive'.

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

The 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).

Sensitivity assessment. At the pressure benchmark organic inputs are unlikely to significantly affect the structure of the biological assemblage or impact the physical habitat, due to remobilisation and transport by wave or currents. 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.

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

The biotope is characterized by the sedimentary habitat (JNCC, 2015), a change to an artificial or rock substratum would alter the character of the biotope leading to reclassification and the loss of the sedimentary community including the characterizing polychaetes and amphipods.

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

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

The pressure benchmark refers to the simplified Folk classification developed by Long (2006) and the UK Marine Habitat Classification Littoral and Sublittoral Sediment Matrices (Connor *et al*., 2004). The biotope occurs on mobile sands, a change at the pressure benchmark refers to a change to sandy muds or muddy sands or to coarser gravel sediments. Experiments by Van Tomme *et al*. (2013) have shown that the optimal sedimentary habitats for some of he species that characterize this biotope vary slightly. *Bathyporeia pilosa* prefer the finest sediments, although at a subtidal dredge disposal site the change to a finer sediment led to a reduction in the abundance of *Bathyporeia pilosa* (Witt *et al*., 2004). *Bathyporeia sarsi* has a broader preference and also occurred in medium-coarse sediments (Van Tomme *et al*., 2013).

Nepthys cirrosa occurs in fine to coarser sands, with greatest abundance in the Belgium part of the North Sea recorded in medium grain sizes (Degraer *et al*., 2006). A change to gravelly sand is unlikely to impact this species, however, a change to muddy sand may limit the species abundance as the species displays a slight preference for low mud content levels (< 10%) (Degraer *et al*., 2006).

Sensitivity assessment. A change to either a finer muddy sediment or a coarser sediment, is likely to lead to changes in the abundance and identity of the characterizing species . Based on the loss of the biotope, resistance is assessed as 'None', recovery is assessed as 'Very low' (as the change at the pressure benchmark is permanent and sensitivity is assessed as 'High'.

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

Bathyporeia pelagica lives infaunally in the uppermost 3 cm of sandy substrata as does the isopod *Eurydice pulchra* (Fish, 1970). Extraction of the sediment to 30cm is likely to remove the characterizing polychaetes, amphipods and isopods within the footprint (although if disturbed some may be able to escape).

Sensitivity assessment. Biotope resistance to extraction of sediment and characterizing species is assessed as 'None. Resilience is assessed as 'High', as sediment recovery will be enhanced by wave action and mobility of sand. The characterizing species are likely to recover through transport of adults in the water column or migration from adjacent patches. Biotope sensitivity is therefore assessed as 'Medium'.

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

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). Similarly, the polychaete *Nephtys cirrosa* is adapted to life in unstable sediments and lives within the sediment. This characteristic is likely to protect this species from surface abrasion.

Comparisons between shores with low and high levels of trampling found that the amphipod *Bathyporeia pelagica* is sensitive to abrasion and compaction from human trampling, other species including *Pontocrates arenarius* and the isopod *Eurydice affinis* also decreased in response to trampling but *Bathyporeia pelagica* appeared to be the most sensitive (Reyes-Martínez *et al*., 2015).

Sensitivity assessment. Resistance to a single abrasion event is assessed as 'Low' based on the evidence for trampling from Reyes-Martínez *et al*. (2015). Resilience is assessed as 'High', based on migration from adjacent populations and in-situ reproduction by surviving amphipods. Sensitivity is therefore assessed as 'Low'. This assessment may underestimate sensitivity to high-levels of abrasion (repeated events within a short period). The trampling evidence and the evidence for penetration from mobile gears (see below) differ in the severity (resistance) of impact. This may be due to different levels of intensity (multiple trampling/abrasion events vs single penetration/towed gear impacts) or the nature of the pressure. Abrasion from trampling also involves a level of compaction that could collapse burrows and damage species through compression. Penetration may, however, break sediments open allowing mobile species to escape or species may be pushed forwards from towed gear by a pressure wave where this is deployed subtidally (Gilkinson *et al*., 1998). Both risk assessments are considered applicable to single events based on the evidence and the sensitivity assessment for both pressures is the same although resistance differs.

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

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).

Bergman and Santbrink (2000) found that direct mortality of gammarid amphipods, following a single passage of a beam trawl (in silty sediments where penetration is greater) was 28%. Similar results were reported from experiments in shallow, wave disturbed areas, using a toothed, clam dredge. *Bathyporeia* spp. experienced a reduction of 25% abundance in samples immediately after intense clam dredging, abundance recovered after 1 day (Constantino *et al*. 2009). Experimental hydraulic dredging for razor clams resulted in no statistically significant differences in *Bathyporeia elegans* abundances between treatments after 1 or 40 days (Hall *et al*., 1990), suggesting that recovery from effects was very rapid. Ferns *et al*. (2000) examined the effects of a tractor-towed cockle harvester on benthic invertebrates and predators in intertidal plots of muddy and clean sand. Harvesting resulted in the loss of a significant proportion of the most common invertebrates from both areas. In the muddy sand, the population of *Bathyporeia pilosa* remained significantly depleted for more than 50 days, whilst the population in clean sand recovered more quickly. These results agree with other experimental studies that clean sands tend to recover more quickly that other habitat types with higher proportions of fine sediment (Dernie *et al*., 2003).

Sensitivity assessment. Based on the evidence above it is considered that *Bathyporeia* spp. and other characterizing species will have 'Medium' resistance (mortality <25%) to abrasion, their small size, infaunal position and mobility enabling a large proportion of the population to escape injury. Recovery is assessed as 'High' and sensitivity is therefore categorised as 'Low'.The trampling evidence (see above) and the evidence for penetration from mobile gears differ in the severity (resistance) of impact. This may be due to different levels of intensity (multiple trampling/abrasion events vs single penetration/towed gear impacts) or the nature of the pressure. Abrasion from trampling also involves a level of compaction that could collapse burrows and damage species through compression. Penetration may, however, break sediments open allowing mobile species to escape or species may be pushed forwards from towed gear by a pressure wave where this is deployed subtidally (Gilkinson *et al.*, 1998).

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

The characterizing species live within the sand and are unlikely to be directly affected by an increased concentration of suspended matter in the water column. Within the mobile sands habitat storm events or spring tides may re-suspend or transport large amounts of material and therefore species are considered to be adapted to varying levels of suspended solids.

Bathyporeia spp. feed on diatoms within the sand grains (Nicolaisen & Kanneworff, 1969), an increase in suspended solids that reduced light penetration could alter food supply. However, diatoms are able to photosynthesise while the tide is out and therefore a reduction in light during tidal inundation may not affect this food source , depending on the timing of the tidal cycle.

Amphipods may be regular swimmers within the surf plankton, where the concentration of suspended particles would be expected to be higher (Fincham, 1970a). Furthermore, during the winter, when *Bathyporeia pelagica* extends its distribution into the mouths of estuaries the species may encounter concentrations of suspended sediment measurable in grams per litre (benchmark is mg/l) (Cole *et al*. 1999).

Sensitivity assessment. Increased inorganic suspended solids may increase abrasion but it is likely that the infaunal species would be unaffected. The biotope is considered to be 'Not sensitive' to a decrease in suspended solids that does not affect sediment transport and supply to the biotope. Biotope resistance is assessed as 'Medium' as some effects on feeding and diatom productivity may occur from increases in suspended solids, resilience is assessed as 'High', following a return to usual conditions and sensitivity is assessed as 'Low'. This more precautionary assessment is presented in the table. Indirect effects such as deposition, erosion and associated sediment change that may result from changes in suspended solids in the long-term are assessed separately.

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

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 *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.

Sensitivity assessment. As the biotope is associated with wave exposed habitats or those with strong currents, some sediment removal will occur, mitigating the effect of deposition. The mobile polychaete *Nephtys cirrosa* and amphipods are likely to be able to burrow through a 5cm layer of fine sediments. Biotope resistance is therefore assessed as 'High' and resilience as 'High' (by default). The biotope is therefore considered to be 'Not sensitive' to this pressure. Repeated deposits or deposits over a large area or in sheltered systems that were shifted by wave and tidal action may result in sediment change (see physical change pressure).

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

Studies have found that beach 'replenishment' or 'nourishment' that involves the addition of sediments on beaches can have a number of impacts on the infauna (Peterson *et al*., 2000, Peterson *et al*., 2006). Impacts are more severe when the sediment added differs significantly in grain size or organic content (Nelson *et al*., 1989, Peterson *et al*., 2000). For example, Maurer *et al*. (1981) found that the amphipod *Parahaustorius longimerus* which occurs intertidally in clean, well-sorted sands and is an active, effective burrower was able to regain the surface after being buried by sand far more easily than when buried under silt/clay mixtures.

A thick layer of sediment has a smothering effect and in most instances buried species will die although some polychaetes can escape up to 90cm of burial In response to nourishment (Speybroek *et al*., 2007, references therein). Peterson *et al*. (2000) found that the dominant macrofauna were reduced by 86-99% 5-10 weeks after the addition of sediment that was finer than the original sediments but with a high shell content.

Little empirical information was found for the ability of characterizing species to reach the surface after burial. Bijkerk (1988, results cited from Essink, 1999) found that the maximal overburden through which *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 and no information was available for other characterizing species.

Leewis *et al*. (2012) investigated the recovery of *Bathyporeia sarsi*, 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).

Repeated events are not considered at the pressure benchmark but it is noted that annual beach nourishment can alter beach sediments (see physical change pressure) and result in suppression of macroinvertebrate populations (Manning *et al*., 2014).

Sensitivity assessment. The thickness of sediment applied during beach nourishment is likely to exceed the 30cm pressure benchmark but the results from studies on the activity are informative, particularly with regard to recovery rate. Sediment removal by wave action could mitigate the level of effect but overall smothering by fine sediments is likely to result in mortality of characterizing amphipods and isopods and possibly *Nephtys cirrosa*. Biotope resistance is therefore assessed as 'Low' and resilience as High (based on Leewis *et al*., 2012), biotope sensitivity is therefore assessed as 'Low'.

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

This pressure is not assessed. Amphipods may also consume microplastics although no negative effects have been documented. Ugolini *et al*. (2013) found that *Talitrus saltator* could consume polyethylene microspheres. Most microspheres were expelled in 24 h. and were totally expelled in one week. microsphere ingestion on the survival capacity in the laboratory. Analyses carried out on faeces of freshly collected individuals revealed the presence of polyethylene and polypropylene, confirming that microplastic debris could be swallowed by *Talitrus saltator* in natural conditions. The talitrid *Orchestia gammarellus* has also been recorded as ingesting microplastics in the size range 20-200µm (Thompson *et al*., 2004).

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 for the characterizing species was found to assess this pressure. For some amphipods there is evidence for geomagnetic orientation being inhibited or disrupted by the presence of electromagnetic fields or by changing magnetic fields. Arendse & Barendregt (1981) manipulated magnetic fields to alter orientation of the talitrid amphipod *Orchestia cavimana*.

Deep-water amphipods *Gondogenia arctica* have been shown to be sensitive to even weak electromagnetic fields which cancel magnetic orientation (Tomanova & Vacha, 2016). Loss of orientation was observed at a radiofrequency electromagnetic field of 2 nT (0.002 µT) (Tomanova & Vacha, 2016).

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

Not relevant.

Introduction of light or shading	Medium Q: High A: Low C: Low	High Q: High A: Low C: High	Low Q: High 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 the 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). Hartwick (1976) found that artificial lighting interfered with learning or orientation cues by Talitrids.

Orientation by light has been well studied for intertidal amphipods (particularly *Talitrus saltator).* Intertidal amphipods orientate themselves by a range of factors that include (but are not limited to) visual cues based on solar or astronomic cues such as the moon and the geomagnetic field (Scapini, 2014). Activity patterns are also linked to internal biological clocks that respond to diel, tidal, lunar and seasonal cycles, so that animals are active during the most suitable time of day or night (Scapini, 2014). The introduction of light or an increase in shading could, therefore, alter behavioural patterns and navigation.

Changes in light and level of shade may indirectly affect the characterizing *Bathyporeia* spp. through changes in behaviour and food supply via photosynthesis of diatoms within sediments. Benthic microalgae play a significant role in system productivity and trophic dynamics, as well as habitat characteristics such as sediment stability (Tait & Dipper, 1998). Shading could prevent photosynthesis leading to death or migration of sediment diatoms altering sediment cohesion and food supply to the grazing amphipods.

Sensitivity assessment. Changes in light are not considered to directly affect the biotope however, some changes in behaviour or food supply for *Bathyporeia* spp could result. Sensitivity is assessed as 'Medium' and resilience is assessed as 'High'. Biotope sensitivity is, therefore, assessed as 'Low'.

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

As the 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 such as the characterizing *Nephtys cirrosa*. 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'.

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

Not relevant' to seabed habitats. NB. Collision by grounding vessels is addressed under 'surface abrasion.

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

The characterizing species are likely to be able to detect light and some movement but are unlikely to have any visual acuity and are considered to not be sensitive to this factor. The amphipods emerge from the sediments at night and are unlikely to be disturbed although like many species they may flee from movements.

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

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

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

The 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 Gateway 2016). This species prefers lower salinities and is typical of brackish waters (Kotta *et al*., 2013) and is therefore not considered a threat to this biotope where salinities are unaltered from the usual full salinity conditions.

Sensitivity assessment. The sediments characterizing this biotope are mobile and frequent disturbance limits the establishment of marine and coastal invasive non-indigenous species as the habitat conditions are unsuitable for most species, as exemplified by the low species richness characterizing this biotope.This biotope is therefore considered to have 'High' resistance to this pressure and high resilience (by default), and is assessed as 'Not sensitive' to this pressure.

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

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).

No evidence was found for pathogen/parasite outbreaks that may result in mass-mortalities in the characterizing species and this pressure is not assessed.

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

Intertidal populations of *Nepthys cirrosa may be targeted by bait diggers.* There is limited information on the effect of digging directly on *Nephtys cirrosa* populations, however there is evidence on effects on another *Nephtys* species: *Nephtys hombergii*. *Nephtys hombergii* is directly removed through commercial bait digging and by recreational anglers and abundance significantly decreased in areas of the Solent, UK, where bait digging (primarily for *Nereis virens*) had occurred (Watson *et al.* 2007). Recovery of *Nephtys hombergii* has been assessed to be very high as re-population would occur initially relatively rapidly via adult migration and later by larval recruitment. Dittman *et al*. (1999) observed that *Nephtys hombergii* was amongst the macrofauna that colonized experimentally disturbed tidal flats within two weeks of the disturbance that caused defaunation of the sediment. However, if sediment is damaged recovery is likely to be slower, for instance *Nephtys hombergii* abundance was reduced by 50% in areas where tractor towed cockle harvesting was undertaken on experimental plots in Burry inlet, south Wales, and had not recovered after 86 days (Ferns *et al.*, 2000).

Sensitivity assessment. Although *Nephtys cirrosa* may be targeted by bait differs where this species occurs intertidally, subtidal populations are not considered to be impacted unless there was a change in emergence regime. This pressure is, therefore considered to be 'Not relevant' to the assessed biotope.

Removal of non-target species	Low Q: Low A: NR C: NR	High Q: High A: High 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. The polychaete *Nephtys cirrosa* and the amphipods are predated on by flat fish and other invertebrate predators during tidal inundation (Speybroeck *et al.*, 2007; Van Tomme *et al.*, 2014).

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 LS.LSa.MoSa group as some examples, particularly those that are very exposed to wave action, contain few species at low abundance (JNCC, 2015).

Bibliography

Alheit, J. & Naylor, E., 1976. Behavioural basis of intertidal zonation in *Eurydice pulchra* Leach. *Journal of Experimental Marine Biology and Ecology*, **23**, 135-144.

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

Arendse, M.C. & Barendregt, A., 1981. Magnetic orientation in the semi-terrestrial amphipod, *Orchestia cavimana*, and its interrelationship with photo-orientation and water loss. *Physiological Entomology*, **6** (4), 333-342.

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

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

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

Batten, L.A., Bibby, C.J., Clement, P., Elliott, G.D. & Porter, R.F., 1990. Red data birds in Britain, The Nature Conservancy Council and RSPB. T. & A.D. Poyser.

Beaumont, A.R., Newman, P.B., Mills, D.K., Waldock, M.J., Miller, D. & Waite, M.E., 1989. Sandy-substrate microcosm studies on tributyl tin (TBT) toxicity to marine organisms. *Scientia Marina*, **53**, 737-743.

Bergman, M.J.N. & Van Santbrink, J.W., 2000b. Fishing mortality of populations of megafauna in sandy sediments. In *The effects of fishing on non-target species and habitats* (ed. M.J. Kaiser & S.J de Groot), 49-68. Oxford: Blackwell Science.

Bethel, W.M. & Holmes, J.C., 1977. Increased vulnerability of amphipods to predation owing to altered behavior induced by larval acanthocephalans. *Canadian Journal of Zoology*, **55** (1), 110-115.

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

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.

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.]

Bryan, G.W. & Gibbs, P.E., 1991. Impact of low concentrations of tributyltin (TBT) on marine organisms: a review. In: *Metal ecotoxicology: concepts and applications* (ed. M.C. Newman & A.W. McIntosh), pp. 323-361. Boston: Lewis Publishers Inc.

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.

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

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

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

Cole, S., Codling, I.D., Parr, W. & Zabel, T., 1999. Guidelines for managing water quality impacts within UK European Marine sites. *Natura 2000 report prepared for the UK Marine SACs Project.* 441 pp., Swindon: Water Research Council on behalf of EN, SNH, CCW, JNCC, SAMS and EHS. [UK Marine SACs Project.], http://www.ukmarinesac.org.uk/

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

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/

Connor, D.W., Dalkin, M.J., Hill, T.O., Holt, R.H.F. & Sanderson, W.G., 1997a. Marine biotope classification for Britain and Ireland. Vol. 2. Sublittoral biotopes. *Joint Nature Conservation Committee, Peterborough, JNCC Report* no. 230, Version 97.06., *Joint Nature Conservation Committee, Peterborough, JNCC* Report no. 230, Version 97.06.

Constantino, R., Gaspar, M., Tata-Regala, J., Carvalho, S., Cúrdia, J., Drago, T., Taborda, R. & Monteiro, C., 2009. Clam dredging effects and subsequent recovery of benthic communities at different depth ranges. *Marine Environmental Research*, **67**, 89-99.

Crisp, D.J. (ed.), 1964. The effects of the severe winter of 1962-63 on marine life in Britain. *Journal of Animal Ecology*, **33**, 165-210.

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.

de-la-Ossa-Carretero, J., Del-Pilar-Ruso, Y., Loya-Fernández, A., Ferrero-Vicente, L., Marco-Méndez, C., Martinez-Garcia, E. & Sánchez-Lizaso, J., 2016. Response of amphipod assemblages to desalination brine discharge: impact and recovery. *Estuarine, Coastal and Shelf Science*, **172**, 13-23

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.

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.

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

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.*

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

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.

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.

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.

Fincham, A.A., 1970a. Amphipods in the surf plankton. *Journal of the Marine Biological Association of the United Kingdom*, **50**, 177-198.

Fincham, A.A., 1970b. Rhythmic behaviour of the intertidal amphipod *Bathyporeia pelagica*. *Journal of the Marine Biological Association of the United Kingdom*, **50**, 1057-1068.

Fish, J.D. & Fish, S., 1972. The swimming rhythm of *Eurydice pulchra* Leach and a possible explanation of intertidal migration. *Journal of Experimental Marine Biology and Ecology*, **8**, 195-200.

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.

Fish, S., 1970. The biology of *Eurydice pulchra* (Crustacea: Isopoda). *Journal of the Marine Biological Association of the United Kingdom*, **50**, 753-768.

Gibbons, D.W., Reid, J.B. & Chapman, R.A., 1993. *The new atlas of breeding birds in Britain and Ireland.* T. & A.D. Poyser.

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.

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

Green Etxabe, A. & Ford, A., 2014. Do demon shrimp carry demon parasites? *Freshwater Biological Association News*, **62**, 10-11.

Hall, S.J., Basford, D.J. & Robertson, M.R., 1990. The impact of hydraulic dredging for razor clams *Ensis* spp. on an infaunal community. *Netherlands Journal of Sea Research*, **27**, 119-125.

Hamond, R., 1966. The Polychaeta of the coast of Norfolk. *Cahiers de Biologie Marine*, **7**, 383-436.

Hartwick, R., 1976. Beach orientation in talitrid amphipods: capacities and strategies. *Behavioral Ecology and Sociobiology*, **1** (4), 447-458.

Hayward, P.J. 1994. *Animals of sandy shores.* Slough, England: The Richmond Publishing Co. Ltd. [Naturalists' Handbook 21.]

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

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

Jänes, H., Kotta, J. & Herkül, K., 2015. High fecundity and predation pressure of the invasive *Gammarus tigrinus* cause decline of indigenous gammarids. *Estuarine, Coastal and Shelf Science*, **165**, 185-189.

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/

JNCC (Joint Nature Conservation Committee), 1999. *Marine Environment Resource Mapping And Information Database (MERMAID): Marine Nature Conservation Review Survey Database*. [on-line] http://www.jncc.gov.uk/mermaid

Jones, D.A. & Naylor, E., 1970. The swimming rhythm of the sand beach isopod *Eurydice pulchra*. *Journal of Experimental Marine Biology and Ecology*, **4**, 188-199.

Jones, D.A., 1970. Population densities and breeding in *Eurydice pulchra* and *Eurydice affinis* in Britain. *Journal of the Marine Biological Association of the United Kingdom*, **50**, 635-655.

Jones, D.A., 1970b. Factors affecting the distribution of the intertidal isopods *Eurydice pulchra* Leach and *E. affinis* Hansen in Britain. *Journal of Animal Ecology*, **39**, 455-472.

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.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.

Khayrallah, N.H. & Jones, A.M., 1980a. The ecology of *Bathyporeia pilosa* (Amphipoda: Haustoriidae) in the Tay Estuary. 1. Factors influencing the distribution on Tayport and Tentsmuir beaches. *Proceedings of the Royal Society of Edinburgh. B*, **78**, 109-119.

Khayrallah, N.H. & Jones, A.M., 1980b. The ecology of *Bathyporeia pilosa* (Amphipoda: Haustoriidae) in the Tay Estuary. 2. Factors affecting the micro-distribution. *Proceedings of the Royal Society of Edinburgh. B*, **78**, 121-130.

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

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.

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.

Kotta, J., Pärnoja, M., Katajisto, T., Lehtiniemi, M., Malavin, S.A., Reisalu, G. & Panov, V.E., 2013. Is a rapid expansion of the invasive amphipod *Gammarus tigrinus* Sexton, 1939 associated with its niche selection: a case study in the Gulf of Finland, the Baltic Sea. *Aquatic Invasions*, **8** (3), 319-332.

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

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.

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

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.

Majeed, S.A., 1987. Organic-matter and biotic indexes on the beaches of North Brittany. *Marine Pollution Bulletin*, **18**, 490-495.

Manning, L.M., Peterson, C.H. & Bishop, M.J., 2014. Dominant macrobenthic populations experience sustained impacts from annual disposal of fine sediments on sandy beaches. *Marine Ecology Progress Series*, **508**, 1-15.

Maurer, D., Keck, R.T., Tinsman, J.C. & Leathem, W.A., 1981. Vertical migration and mortality of benthos in dredged material: Part II—crustacea. *Marine Environmental Research*, **5** (4), 301-317.

McIntyre, A.D. & Eleftheriou, A., 1968. The bottom fauna of a flatfish nursery ground. *Journal of the Marine Biological Association of the United Kingdom*, **48**, 113-142.

McIntyre, A.D., 1969. Ecology of marine meiobenthos. *Biological Reviews*, **44**, 245-290.

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

McLachlan, A., 1980. Exposed sandy beaches as semi-enclosed ecosystems. *Marine Environmental Research*, **4**, 59-63.

McLachlan, A., 1983. Sandy beach ecology - a review. In *Sandy beaches as ecosystems* (ed. A. McLachlan & T. Erasmus), pp.321-381. The Hague: Dr W. Junk Publishers.

McLachlan, A., Wooldridge, T. & Dye, A.H., 1981. The ecology of sandy beaches in Southern Africa. *South African Journal of Zoology*, **16**, 219-231.

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

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.

Meador, J.P., Varanasi, U. & Krone, C.A., 1993. Differential sensitivity of marine infaunal amphipods to tributyltin. *Marine Biology*, **116**, 231-239.

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.

Menn, I., Junghans, C. & Reise, K., 2003. Buried alive: effects of beach nourishment on the infauna of an erosive shore in the North Sea. *Senckenbergiana Maritima*, **32** (1-2), 125-145.

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.

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

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.

Olive, P.J.W. & Morgan, P.J., 1991. The reproductive cycles of four British intertidal *Nephtys* species in relation to their geographical distribution (Polychaeta: Nephtyidae). *Ophelia*, Supplement 5, 351-361.

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

Peterson, C.H., Bishop, M.J., Johnson, G.A., D'Anna, L.M. & Manning, L.M., 2006. Exploiting beach filling as an unaffordable experiment: benthic intertidal impacts propagating upwards to shorebirds. *Journal of Experimental Marine Biology and Ecology*, **338** (2), 205-221.

Peterson, C.H., Hickerson, D.H. & Johnson, G.G., 2000. Short-term consequences of nourishment and bulldozing on the dominant large invertebrates of a sandy beach. Journal of Coastal Research, 368-378.

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.

Preece, G.S., 1971. The swimming rhythm of *Bathyporeia pilosa* (Crustacea: Amphipoda). *Journal of the Marine Biological Association of the United Kingdom*, **51**, 777-791.

Quartel, S., Kroon, A. & Ruessink, B., 2008. Seasonal accretion and erosion patterns of a microtidal sandy beach. *Marine Geology*, **250** (1), 19-33.

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**, 717-730.

Scapini, F., 2014. Behaviour of mobile macrofauna is a key factor in beach ecology as response to rapid environmental changes. *Estuarine Coastal and Shelf Science*, **150**, 36-44.

Sherman, K.M. & Coull, B.C., 1980. The response of meiofauna to sediment disturbance. *Journal of Experimental Marine Biology and Ecology*, **46**, 59-71.

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.

Speybroeck, J., Alsteens, L., Vincx, M. & Degraer, S., 2007. Understanding the life of a sandy beach polychaete of functional importance–*Scolelepis squamata* (Polychaeta: Spionidae) on Belgian sandy beaches (northeastern Atlantic, North Sea). *Estuarine, Coastal and Shelf Science*, **74** (1), 109-118.

Speybroeck, J., Van Tomme, J., Vincx, M. & Degraer, S., 2008. In situ study of the autecology of the closely related, co-occurring sandy beach amphipods *Bathyporeia pilosa* and *Bathyporeia sarsi*. *Helgoland Marine Research*, **62** (3), 257-268.

Steele, J.H. & Baird, I.E., 1968. Production ecology of a sandy beach. *Limnology and Oceanography*, **13**, 14-25.

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.

Thompson, R.C., Olsen, Y., Mitchell, R.P., Davis, A., Rowland, S.J., John, A.W., McGonigle, D. & Russell, A.E., 2004. Lost at sea: where is all the plastic? *Science*, **304** (5672), 838-838.

Tomanová, K. & Vácha, M., 2016. The magnetic orientation of the Antarctic amphipod *Gondogeneia antarctica* is cancelled by very weak radiofrequency fields. *Journal of Experimental Biology*, **219**, 1717-1724.

Ugolini, A., Ungherese, G., Somigli, S., Galanti, G., Baroni, D., Borghini, F., Cipriani, N., Nebbiai, M., Passaponti, M. & Focardi, S., 2008. The amphipod *Talitrus saltator* as a bioindicator of human trampling on sandy beaches. *Marine Environmental Research*, **65** (4), 349-357.

Van Tomme, J., Degraer, S. & Vincx, M., 2014. Role of predation on sandy beaches: Predation pressure and prey selectivity estimated by laboratory experiments. *Journal of Experimental Marine Biology and Ecology*, **451**, 115-121.

Van Tomme, J., Eede, S.V., Speybroeck, J., Degraer, S. & Vincx, M., 2013. Macrofaunal sediment selectivity considerations for beach nourishment programmes. *Marine Environmental Research*, **84**, 10-16.

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.

Watkin, E.E., 1939(b). The pelagic phase in the life history of the amphipod genus *Bathyporeia*. *Journal of the Marine Biological Association of the United Kingdom*, **23**, 467-481.

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.

Withers, R.G. & Thorp, C.M., 1978. The macrobenthos inhabiting sandbanks in Langstone Harbour, Hampshire. *Journal of Natural History*, **12**, 445-455.