



MarLIN

Marine Information Network

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

Fabulina fabula and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand

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

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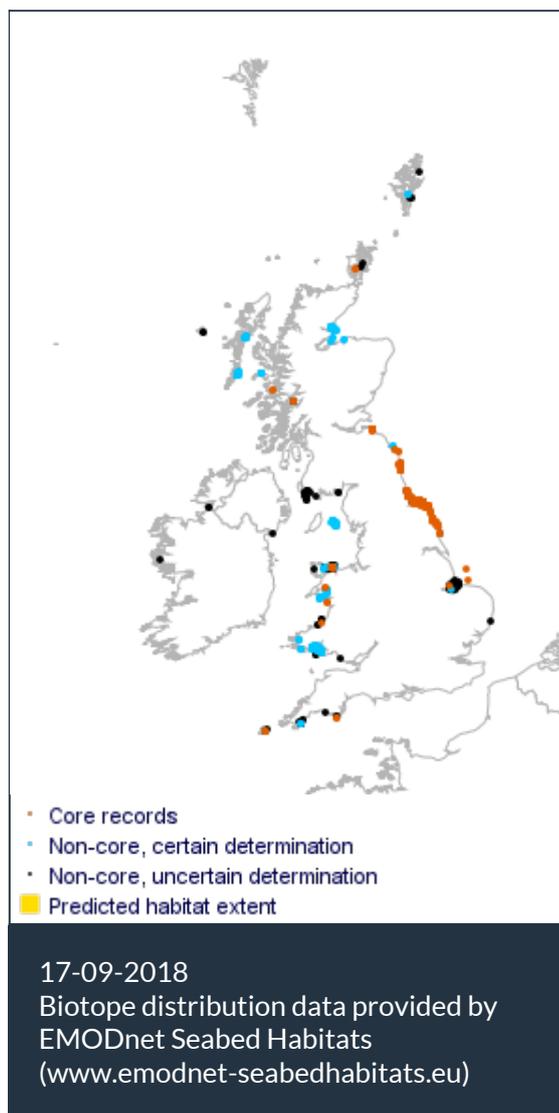
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Researched by Dr Heidi Tillin & Will Rayment

Refereed by Admin

Summary

☰ UK and Ireland classification

EUNIS 2008 A5.242

Fabulina fabula and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand

JNCC 2015 SS.SSa.IMuSa.FfabMag

Fabulina fabula and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand

JNCC 2004 SS.SSa.IMuSa.FfabMag

Fabulina fabula and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand

1997 Biotope SS.IGS.FaS.FabMag

Fabulina fabula and *Magelona mirabilis* with venerid bivalves in infralittoral compacted fine sand

🔍 Description

In stable, fine, compacted sands and slightly muddy sands in the infralittoral and littoral fringe, communities occur that are dominated by venerid bivalves such as *Chamelea gallina*. This biotope

may be characterized by a prevalence of *Fabulina fabula* and *Magelona mirabilis* or other species of *Magelona* (e.g. *Magelona filiformis*). Other taxa, including the amphipod *Bathyporeia* spp. and polychaetes such as *Chaetozone setosa*, *Spiophanes bombyx* and *Nephtys* spp. are also commonly recorded. In some areas the bivalve *Spisula elliptica* may also occur in this biotope in low numbers. The community is relatively stable in its species composition, however, numbers of *Magelona* and *Fabulina fabula* tend to fluctuate. Around the Scilly Isles numbers of *Fabulina fabula* in this biotope are uncommonly low whilst these taxa are often found in higher abundances in muddier communities (presumably due to the higher organic content). Consequently it may be better to revise this biotope on the basis of less ubiquitous taxa such as key amphipod species (E.I.S. Rees pers. comm. 2002) although more data is required to test this. FfabMag and MoeVen are collectively considered to be the 'shallow Venus community' or 'boreal off-shore sand association' of previous workers (see Petersen 1918; Jones 1950; Thorson 1957). These communities have been shown to correlate well with particular levels of current induced 'bed-stress' (Warwick & Uncles 1980). The 'Arctic Venus Community' and 'Mediterranean Venus Community' described to the north and south of the UK (Thorson 1957) probably occur in the same habitat and appears to be the same biotope described as the *Ophelia borealis* community in northern France and the central North Sea (Könitzer et al. 1992). Sites with this biotope may undergo transitions in community composition. The epibiotic biotopes EcorEns and AreISa may also overlay this biotope in some areas (JNCC, 2015)

↓ Depth range

5-10 m, 10-20 m, 20-30 m

🏛️ Additional information

There is a degree of uncertainty concerning the habitat preferences of the species which characterize the IGS.FabMag biotope. The biotope appears to be based on the 'Tellina sub-community' described by Warwick & Davis (1977) and Warwick & Uncles (1980), which occurs in stable sands sheltered from big swells and with low tidal stress. The characterizing species are described as being fragile, for instance, *Fabulina fabula* with a "thin, brittle shell" and *Magelona mirabilis* with "long, delicate palps". The authors suggest that *Fabulina fabula* and *Magelona mirabilis* are absent from more dynamic areas with high sediment transport, where they are replaced by more robust species, such as *Spisula elliptica* and *Nephtys cirrosa*. However, literature research on the biology and ecology of *Magelona mirabilis* suggests it is a heavily r-selected opportunist species adapted to life in mobile sands (see Bosselmann, 1989; Niermann et al., 1990; Kröncke, 1990). Additionally, Elliott et al. (1998) place IGS.FabMag in the 'subtidal mobile sandbanks' complex, where the composite species are adapted to variable hydrography and a mobile substratum. It appears that the biotope is likely to contain elements of both relatively stable sands, characterized by climax species such as *Fabulina fabula* and *Nephtys hombergii*, and more dynamic sands, characterized by *Spisula elliptica* and *Nephtys cirrosa*. Even stable sands are liable to perturbations from variable environmental conditions and hence species characteristic of early successional stages, such as *Magelona mirabilis*, are able to persist. For the purposes of this review, species characteristic of the biotope are assumed to be those favouring stable conditions, e.g. *Fabulina fabula*, and the characteristic opportunists, e.g. *Magelona mirabilis*.

✓ Listed By

- none -

Further information sources

Search on:



Habitat review

🔄 Ecology

Ecological and functional relationships

- The hydrodynamic regime, sediment composition and interaction between the two are probably the most significant factors structuring the community of the biotope rather than the biological interactions (Tyler, 1977; Warwick & Uncles, 1980; Elliott *et al.*, 1998).
- The fine sand habitat supports high abundances of suspension feeders (e.g. the bivalves *Chamelea gallina*, *Gari fervensis* and *Donax vittatus*), deposit feeders (e.g. the polychaetes *Magelona mirabilis*, *Spiophanes bombyx* and *Chaetozone setosa*) and species with flexible feeding methods (e.g. the bivalve *Fabulina fabula* and the tube building polychaete *Lanice conchilega*).
- The amphipods (e.g. *Bathyporeia guilliamsoniana*, *Bathyporeia elegans* and *Ampelisca brevicornis*) and the infaunal annelid species in the biotope probably interfere strongly with each other. Adult worms probably reduce amphipod numbers by disturbing their burrows and tubes, while high densities of amphipods can prevent establishment of worms by consuming larvae and juveniles (Olafsson & Persson, 1986).
- Spatial competition probably occurs between the infaunal suspension feeders and deposit feeders. Reworking of sediment by deposit feeders makes the substratum less stable, increases the suspended sediment and makes the environment less suitable for suspension feeders (Rhoads & Young, 1970). Tube building by amphipods and polychaetes stabilizes the sediment and arrests the shift towards a community consisting entirely of deposit feeders.
- Amphipods are predated chiefly by nemertean worms (e.g. McDermott, 1984) and demersal fish (Costa & Elliott, 1991).
- The abundant infauna are preyed upon by carnivorous polychaetes, e.g. *Nephtys hombergii*.
- The echinoderms, *Astropecten irregularis* and *Asterias rubens*, predate the bivalves (Aberkali & Trueman, 1985; Elliott *et al.*, 1998).
- Crabs, particularly *Liocarcinus depurator*, are scavengers and predators of molluscs and annelids (Thrush, 1986; Elliott *et al.*, 1998).

Seasonal and longer term change

- Temporal changes are likely to occur in the community due to seasonal recruitment processes. In the German Bight, peak abundance of *Fabulina fabula* (ca 2000 individuals/m²) occurred in September following the main period of spatfall and then decreased to a minimum in February (ca 500 individuals/m²), at which point settlement began to occur again (Salzwedel, 1979). Similarly, temporal evolution of *Fabulina fabula* in NW Spain showed well marked annual peaks in autumn (Lopez-Jamar *et al.*, 1995). In the German Bight, spatfall for *Magelona mirabilis* was heaviest in August/September, and for *Echinocardium cordatum* spatfall was heaviest in August (Bosselmann, 1989).
- Temporal variations in species richness and abundance are likely to occur due to seasonal patterns of disturbance, such as storms, harsh winters and oxygen deficiencies (Bosselmann, 1989; Lopez-Jamar *et al.*, 1995). The biotope may also be liable to severe substratum disturbance, such as one in 25 year or one in 50 year storms, which can turn over sediment and completely disrupt the community (Elliott *et al.*, 1998).
- The water temperature in subtidal sandy habitats may vary over 5-10°C through the year in British coastal waters depending on depth. The variation may have short-term but

significant effects on species diversity (Buchanan & Moore, 1986).

- There may be a spring-neap and winter-summer cycle of erosion and deposition of sediment, altering the biotope extent and reflecting changes in hydrodynamic energy (Dyer, 1998).
- There is a seasonal variation in planktonic production in surface waters which probably affects the food supply of the benthos in the biotope. Increased production by phytoplankton in spring and summer due to increased temperatures and irradiance is followed by phytoplankton sedimenting events which are correlated with seasonal variations in the organic content of benthic sediments (Thouzeau *et al.*, 1996). These variations directly influence the food supply of the deposit feeders and suspension feeders in the biotope.

Habitat structure and complexity

- The spatial extent of the biotope is dictated by the physical conditions, especially the physiography and underlying geology coupled with the hydrodynamic regime, which dictates where and how much sediment will be deposited (Elliott *et al.*, 1998).
- By definition the biotope is fairly homogeneous, although it may occur under variable environmental conditions (Elliott *et al.*, 1998). The uniform fine sand is unlikely to be very sculpted as the biotope occurs in areas of weak tidal streams (Connor *et al.*, 1997a).
- The sediment itself is relatively fluid, but is probably stabilized by the biota. For example, the microphytobenthos in the interstices of the sand grains produce mucilaginous secretions which stabilize fine substrata (Tait & Dipper, 1998), and tube building polychaetes, e.g. *Lanice conchilega* and *Owenia fusiformis*, stabilize the sediment and enhance deposition.

Productivity

Production in the biotope is mostly secondary, derived from detritus and organic material. Some primary production comes from benthic microalgae and water column phytoplankton. The microphytobenthos consists of unicellular eukaryotic algae and cyanobacteria that grow in the upper several millimetres of illuminated sediments, typically appearing only as a subtle brown or green shading (Elliott *et al.*, 1998).

The benthos is supported predominantly by pelagic production and by detrital materials emanating from the coastal fringe (Barnes & Hughes, 1992). The amount of planktonic food reaching the benthos is related to:

- depth of water through which the material must travel;
- magnitude of pelagic production;
- proximity of additional sources of detritus;
- extent of water movement near the sea bed, bringing about the renewal of suspended supplies (Barnes & Hughes, 1992).

Food becomes available to deposit feeders by sedimentation on the substratum surface and by translocation from the water column to the substratum through production of pseudofaeces by suspension feeders.

Productivity in the biotope is expected to be relatively high. The amphipods have a short lifespan, grow to maturity quickly and have multiple generations per year. The biotope also contains many species that occur in early successional stages and have rapid turnovers, for example *Magelona mirabilis*.

The sediment in the biotope may be nutrient enriched due to proximity to anthropogenic nutrient sources such as sewage outfalls or eutrophicated rivers.

Warwick *et al.* (1978) studied the productivity of the fine sand *Venus* community in Carmarthen Bay, Wales. Total production by the macrofauna in the community was 25.8 g/m² per year. *Fabulina fabula* was responsible for 340 mg/m² of this production, with a production:biomass ratio of 0.90. This ratio is relatively low because the species is long lived and has a low turnover. For comparison, the production:biomass ratio of *Magelona mirabilis* was 1.10.

Recruitment processes

- Sandy areas are usually dependent on an input of colonizing organisms and have few species with benthic reproduction. Hence, recruitment is sensitive to changes in the hydrodynamic regime. Sandbanks in particular may be recruitment sinks as they often occur at the centre of hydrographic gyres (Elliott *et al.*, 1998). Of the characterizing species in the biotope, only *Astropecten irregularis* is likely to migrate into the area as adults.
- The bivalves in the biotope are gonochoristic broadcast spawners with pelagic larval dispersal. They therefore have the potential to recruit both locally and remotely. However, bivalve populations typically show considerable pluriannual variations in recruitment, suggesting that recruitment is patchy and/or post settlement processes are highly variable (e.g. Dauvin, 1985). Olafsson *et al.* (1994) reviewed the potential effects of pre and post recruitment processes. Recruitment may be limited by predation of the larval stage or inhibition of settlement due to intraspecific density dependent competition. Post settlement processes affecting survivability include predation by epibenthic consumers, physical disturbance of the substratum and density dependent starvation of recent recruits. Hence, annual predictable recruitment of venerid bivalves probably does not occur in the biotope.
- The dominant polychaetes in the biotope, *Magelona mirabilis* and *Nephtys hombergii*, and the tube building polychaetes, *Lanice conchilega* and *Owenia fusiformis*, disperse via a pelagic larval stage lasting up to 2 months and therefore recruitment may occur from distant populations. However, dispersal of infaunal deposit feeders such as *Scoloplos armiger* occurs through burrowing of the benthic larvae and adults. Recruitment must therefore occur from local populations or by longer distance dispersal during periods of bedload transport. Recruitment is therefore likely to be predictable if local populations exist but will most likely be patchy and sporadic otherwise.
- Both *Fabulina fabula* and *Magelona mirabilis* have heavy spatfalls and the potential for mass development, enabling the population to recover rapidly from disturbance. Spatfall is usually followed by heavy post settlement mortality (Bosselmann, 1989).
- *Magelona mirabilis* appears to settle preferentially in areas already occupied by adults (Bosselmann, 1989).
- The mating system of amphipods is polygynous and several broods of offspring are produced, each potentially fertilised by a different male. There is no larval stage and embryos are brooded in a marsupium, beneath the thorax. Embryos are released as subjuveniles with incompletely developed eighth thoracopods and certain differences in body proportions and pigmentation. Dispersal is limited to local movements of the subjuveniles and migration of the adults and hence recruitment is limited by the presence of local, unperturbed source populations (Poggiale & Dauvin, 2001). Dispersal of subjuveniles may be enhanced by the brooding females leaving their tubes and swimming to uncolonized areas of substratum before the eggs hatch (Mills, 1967).

Time for community to reach maturity

Following a disaster event or exposure of a new substratum, succession in the biotope is likely to follow a predictable sequence (Diaz-Castaneda *et al.*, 1989). Pioneer species, such as *Capitella capitata*, *Magelona mirabilis* and *Scoloplos armiger*, dominate the early successional stages. These species are then partly replaced by regular seasonal species that breed at the same time every year, i.e. the relatively opportunistic bivalves such as *Abra alba*. Finally, the equilibrium species become established, e.g. *Fabulina fabula*, *Chamelea gallina* and *Nephtys hombergii*, characterized by long lifespans and irregular spatfall (Diaz-Castaneda *et al.*, 1989).

The climax species are relatively quick to mature and it is likely that the community would reach maturity within 2-3 years. However, the biotope is vulnerable to physical disturbance and would probably be frequently perturbed, restarting the succession process.

Additional information

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Preferences & Distribution

Habitat preferences

Depth Range	5-10 m, 10-20 m, 20-30 m
Water clarity preferences	
Limiting Nutrients	Field unresearched
Salinity preferences	Full (30-40 psu)
Physiographic preferences	
Biological zone preferences	Infralittoral
Substratum/habitat preferences	Muddy sand
Tidal strength preferences	Moderately Strong 1 to 3 knots (0.5-1.5 m/sec.), Very Weak (negligible), Weak < 1 knot (<0.5 m/sec.)
Wave exposure preferences	Moderately exposed
Other preferences	Medium to very fine sand with some silt

Additional Information

Species composition

Species found especially in this biotope

- *Fabulina fabula*
- *Magelona mirabilis*

Rare or scarce species associated with this biotope

-

Additional information

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The initial project scoping exercise to update the existing MarLIN assessments with the MarESA approach grouped biotopes where sensitivities were likely to be similar. The biotopes SS.SSa.IMuSa.FfabMag; SS.SSa.IMuSa.SsubNhom; SS.SSa.CFiSa.EpusOborApri; SS.SSa.CFiSa.ApriBatPo and SS.SSa.CMuSa.AalbNuc represent a continuum along depth and sediment gradients and were grouped as their responses to pressures are probably similar, given the presence of similar species and functional groups. These biotopes have been reviewed as a group, although the resultant reviews and sensitivity assessments are presented separately for each biotope. The specific biotope assessments have been updated with information on characterizing species, where this was readily available, however, the assessments are relatively generic for this group.

Resilience and recovery rates of habitat

This biotope may recover from impacts via *in-situ* repair of damaged individuals, migration of adults of mobile species such as the errant polychaetes *Glycera lapidum* and *Nephtys cirrosa*, amphipods and urchins. Adults may also be transported in the water column following washout from sediments. Storm events may lead to the displacement of large numbers of individuals. Most bivalves will be able to reposition within the sediment and some, such as *Glycymeris glycymeris*, are also able to move and to relocate following displacement and disturbance (Thomas, 1975). For immobile species or where depopulation has occurred over a large area, recovery will depend on recolonization by pelagic larvae.

A large number of species are recorded in the biotopes within the assessed group and there may be large natural variation in species abundance over the course of a year or between years (see Dauvin, 1985 for *Timoclea ovata*; Fahy *et al.*, 2003 for *Spisula solida*; Sardá *et al.*, 1999 multispecies). These variations may not alter the biotope classification where habitat parameters, such as sediment type, remain as described in the classification and many of the characteristic species groups are present. For many of the bivalve species studied, recruitment is sporadic and depends on a successful spat fall but recruitment by the characterizing polychaetes may be more reliable. However, due to the large number of pre- and post-recruitment factors such as food supply, predation, and competition, recruitment of venerid bivalves and other species is unpredictable (Olafsson *et al.*, 1994).

The life history characteristics of the characterizing bivalves and polychaetes and other species were reviewed. Little information was found for *Moerella* spp. Morton (2009), noted that despite the wide global distribution of the characterizing venerid bivalve, *Timoclea ovata*, little was known about its anatomy or basic biology. This appears to be the case for many of the other characterizing venerid bivalves and much more information was available for the polychaete species that occur in this biotope. Two linked factors that may explain this are the greater research effort in soft sediments with higher mud contents where sampling is easier than in coarse sediments. Venerid bivalves are also considered to be under-represented in grab samples (JNCC, 2015), so less is known of their occurrence on ecological and impact gradients.

The venerid bivalves in the biotope reach sexual maturity within two years, spawn at least once a year and have a pelagic dispersal phase (Guillou & Sauriau, 1985; Dauvin, 1985). No information was found concerning number of gametes produced, but the number is likely to be high as with

other bivalves exhibiting planktotrophic development (Olafsson *et al.*, 1994). Recruitment in venerids is likely to be episodic, some species such as *Chamelea gallina* may be long-lived (11-20 years). The long lifespan & slow growth rate suggest that this group is likely to take several years, even if initial recolonization were to occur rapidly (MES, 2010). Dauvin (1985) reported that *Timoclea ovata* (studied as *Venus ovata*) recruitment occurred in July-August in the Bay of Morlaix. However, the population showed considerable pluriannual variations in recruitment, which suggests that recruitment is patchy and/or post settlement processes are highly variable.

The species that are present in the biotope can be broadly characterized as either opportunist species that rapidly colonize disturbed habitats and increase in abundance, or species that are larger and longer-lived and that may be more abundant in an established, mature assemblage.

Species with opportunistic life strategies (small size, rapid maturation and short lifespan of 1-2 years with production of large numbers of small propagules), include the bivalve *Spisula solida*; and the polychaetes *Spiophanes bombyx*, *Spio filicornis*, and *Chaetozone setosa*; also cumaceans; barnacles *Balanus crenatus*; and the tube worm *Spirobranchus* (formerly *Pomatoceros*) *lamarckii*. These are likely to recolonize disturbed areas first, although the actual pattern will depend on recovery of the habitat, season of occurrence and other factors. The recovery of bivalves that recruit episodically and the establishment of a representative age-structured population for larger, longer lived organisms may require longer than two years. In an area that had been subjected to intensive aggregate extraction for 30 years, abundances of juvenile and adults *Nephtys cirrosa* had greatly increased three years after extraction had stopped (Mouleaert & Hostens, 2007). An area of sand and gravel subject to chronic working for 25 years had not recovered after 6 years when compared to nearby reference sites unimpacted by operations (Boyd *et al.*, 2005). The characterizing *Moerella* (now *Tellina*) spp. 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. Similarly, *Chamelea* sp. and *Dosinia* sp. are long lived (11-20 years and up to 20 years, respectively; MES, 2008, 2010). While recruitment may be rapid, restoration of the biomass by growth of the colonizing individuals is likely to take many years.

Other longer lived species that may represent a more developed and stable assemblage include the polychaete *Owenia fusiformis* which lives for 4 years and reproduces annually (Gentil *et al.*, 1990). *Nephtys* species and *Glycera* spp. are also longer-lived. *Glycera* are monotelic having a single breeding period towards the end of their life but may recover through migration and may persist in disturbed sediments through their ability to burrow (Klawe & Dickie, 1957). *Glycera* spp. have a high potential rate of recolonization of sediments, but the relatively slow growth-rate and long lifespan suggests that recovery of biomass following initial recolonization by post-larvae is likely to take several years (MES, 2010). 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, with high densities of *Spisula subtruncata* and *Owenia fusiformis* in the spring following dredging, although most of these recruits did not survive summer. However, *Glycera* spp. and *Protodorvillea kefersteini* had not recovered within two years (Sardá *et al.*, 2000).

A number of studies have tracked recovery of sand and coarse sand communities following disturbance from fisheries (Gilkinson *et al.*, 2005) and aggregate extraction (Boyd *et al.*, 2005). The available studies confirm the general trend that, following severe disturbance, habitats are recolonized rapidly by opportunistic species (Pearson & Rosenberg, 1978). Experimental deployment of hydraulic clam dredges on a sandy seabed on Banquereau, on the Scotian Shelf, eastern Canada showed that within 2 years of the impact, polychaetes and amphipods had

increased in abundance after 1 year (Gilkinson *et al.*, 2005). Two years after dredging, abundances of opportunistic species were generally elevated relative to pre-dredging levels while communities had become numerically dominated (50-70%) by *Spiophanes bombyx* (Gilkinson *et al.*, 2005). Van Dalfsen *et al.* (2000) found that polychaetes recolonized a dredged area within 5-10 months (reference from Boyd *et al.*, 2005), with biomass recovery predicted within 2-4 years. The polychaete and amphipods are therefore likely to recover more rapidly than the characterizing bivalves and the biotope classification may revert, during recovery, to a polychaete dominated biotope.

Sardá *et al.* (1999) tracked annual cycles within a *Spisula* community in Bay of Blanes (north west Mediterranean sea, Spain) for 4 years. Macroinfaunal abundance peaked in spring, decreased sharply throughout the summer, with low density in autumn and winter. The observed trends were related to a number of species, including many that characterize this biotope such as *Owenia fusiformis*; *Glycera* sp.; *Protodorvillea kefersteini*; *Mediomastus fragilis*; *Spisula subtruncata*; and *Branchiostoma lanceolatum*. The *Spisula subtruncata* populations were dominated by juveniles, with high abundances in spring followed by declines in summer, with very few survivors 3 months after recruitment. Inter-annual differences in recruitment of *Owenia fusiformis* were apparent and this species showed spring/summer increases. *Mediomastus fragilis* also had spring population peaks but more individuals persisted throughout the year. *Protodorvillea kefersteini* exhibited a similar pattern with spring recruitment and a population that persisted throughout the year.

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 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, due to the number of characterizing species and variability in recruitment patterns, 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 recognisable 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)	Medium Q: High A: Low C: Medium	High Q: High A: Low C: Medium	Low Q: High A: Low C: Medium

Davenport & Davenport (2005) demonstrated that the limits of thermal tolerance to high and low temperatures reflect distribution of intertidal macroinvertebrate species. Species that occur highest on the shore are more tolerant of a wider range of temperatures than species that occurred low on the shore or subtidally. As subtidal biotopes are less exposed to temperature fluctuations, the characterizing species may be less able to tolerate temperature fluctuations.

No direct evidence was found to support assessment of this pressure. Very few laboratory studies have been carried out on the characterizing species and the assessment relies on information on larvae in the plankton or monitoring of settlement and records of species distribution. Species from different areas may be acclimated to prevailing conditions and life histories may vary, e.g. *Chamelea gallina* longevity varies between populations (Gaspar *et al.*, 2004) as does the longevity of *Amphipholis squamata* in different locations and habitats (Emson *et al.*, 1989).

Kröncke *et al.* (1998) examined long-term changes in the macrofauna in the subtidal zone off Norderney, one of the East Frisian barrier islands. The analysis suggested that macrofauna were severely affected by cold winters whereas storms and hot summers have no impact on the benthos. A long-term increase in temperature might cause a shift in species composition. Long-term analysis of the North Sea pelagic system has identified yearly variations in larval abundance of Echinodermata, Arthropoda, and Mollusca larvae that correlate with sea surface temperatures. Larvae of benthic echinoderms and decapod crustaceans increased after the mid-1980s, coincident with a rise in North Sea sea surface temperature, whereas bivalve larvae underwent a reduction (Kirby *et al.*, 2008). An increase in temperature may alter larval supply and in the long-term, and over large spatial scales, may result in changes in community composition.

Temperature cues influence the timing of gametogenesis and spawning in several species present in the biotope. Seasonal variations in reproductive cycle of *Spisula solida* were studied at a site off Vilamoura, southern Portugal. The onset of spawning took place in February when the seawater temperature began to increase and spawning ended in May. It is possible that *Spisula solida* does not spawn at a definite temperature, rather responding to the increase in seawater temperature (Gaspar & Monteiro, 1999). Many polychaete species including *Mediomastus fragilis*, *Owenia fusiformis* and *Protodorvillea kefersteini* also show spring/early summer recruitment (Sardá *et al.*, 1999).

Sensitivity assessment. Little evidence was available to assess this pressure. Assemblages in fine sands and muddy sands contain many of the characterizing species occur in the Mediterranean (see resilience section Sardá *et al.*, 1999; Sardá *et al.*, 2000), where temperatures are higher than experienced in the UK. It is considered likely, therefore, that a chronic change in temperature at the pressure benchmark would be tolerated by species with a wide distribution or that some species or groups of species would be resistant. An acute change may exceed thermal tolerances or lead to spawning or other biological effects. These effects may be sub-lethal or result in the removal of only a proportion of less tolerant species. Biotope resistance is therefore assessed as 'Medium' and resilience is assessed as 'High'. Biotope sensitivity is therefore assessed as 'Low'.

Temperature decrease (local)**Medium**

Q: High A: Low C: Medium

High

Q: High A: Low C: Medium

Low

Q: High A: Low C: Medium

Davenport & Davenport (2005) demonstrated that the limits of thermal tolerance to high and low temperatures reflect the distribution of intertidal macroinvertebrate species. Species that occur highest on the shore are more tolerant of a wider range of temperatures than species that occurred low on the shore or subtidally. As subtidal biotopes are less exposed to temperature fluctuations the characterizing species may be less able to tolerate temperature fluctuations.

Long-term analysis of the North Sea pelagic system has identified yearly variations in larval abundance of Echinodermata, Arthropoda, and Mollusca larvae that correlate with sea surface temperatures. Larvae of benthic echinoderms and decapod crustaceans increased after the mid-1980s, coincident with a rise in North Sea sea surface temperature, whereas bivalve larvae underwent a reduction (Kirby *et al.*, 2008). A decrease in temperature may alter larval supply and in the long-term, and over large spatial scales, may result in changes in community composition.

Sensitivity assessment. Many of the characterizing species are found in more northern waters than the UK and may be adapted to colder temperatures. Plankton studies suggest that colder waters may favour bivalve larvae. An acute change may exceed thermal tolerances or lead to spawning or other biological effects. These effects may be sub-lethal or remove only a proportion of less tolerant species. Biotope resistance is therefore assessed as 'Medium' and resilience is assessed as 'High'. Biotope sensitivity is therefore assessed as 'Low'.

Salinity increase (local)**Low**

Q: High A: Low C: NR

Medium

Q: High A: Low C: Medium

Medium

Q: High A: Low C: Low

The assessed biotope occurs in full salinity (30-35 ppt) (JNCC, 2015). A change at the pressure benchmark therefore refers to a change to full salinity. No directly relevant evidence was found to assess this pressure. A study from the Canary Islands indicates that exposure to high salinity effluents (47- 50 psu) from desalination plants alter the structure of biological assemblages, reducing species richness and abundance (Riera *et al.*, 2012). Bivalves and amphipods appear to be less tolerant of increased salinity than polychaetes and were largely absent at the point of discharge. Polychaetes, including species or genera that occur in this biotope, such as *Spio filicornis*, *Glycera* spp. and *Lumbrineris* sp., were present at the discharge point (Riera *et al.*, 2012). The ophiuroid *Amphipholis squamata* has been recorded in areas of high salinity (52-55 ppt) in the Arabian Gulf (Price, 1982), indicating local acclimation may be possible.

Sensitivity assessment. High saline effluents alter the structure of biological assemblages. Polychaete species may be more tolerant than bivalves so that an increase in salinity may lead to a shift in community composition. Biotope resistance is therefore assessed as 'Low' and resilience as 'Medium', as bivalve recovery may depend on episodic recruitment. Biotope sensitivity is assessed as 'Medium'.

Salinity decrease (local)**Low**

Q: Low A: NR C: NR

Medium

Q: High A: Low C: Medium

Medium

Q: Low A: Low C: Low

Species tolerances to decreases in salinity are likely to vary but changes in sensitivity are likely to result in changes in species richness and abundance with some shift in species composition. Biotope resistance is therefore assessed as 'Low' and resilience as 'Medium', as

bivalve recovery may depend on episodic recruitment. Biotope sensitivity is assessed as 'Medium'.

Water flow (tidal current) changes (local)

High

Q: High A: Low C: NR

High

Q: High A: High C: High

Not sensitive

Q: Low A: Low C: Low

This biotope is recorded in areas where tidal flow varies between moderately strong (0.5-1.5 m/s) and weak (>0.5 m/s) (JNCC, 2015). 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. may form following an increase in water flow, or disappear following a reduction in flow.

Sensitivity assessment. This biotope occurs in areas subject to moderately strong water flows and these 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 resistance 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

Changes in emergence are 'Not relevant' to this biotope which is restricted to fully subtidal habitats.

Wave exposure changes (local)

High

Q: Low A: NR C: NR

High

Q: High A: High C: High

Not sensitive

Q: Low A: Low C: Low

As this biotope occurs in sublittoral habitats, it is not directly exposed to the action of breaking waves. Associated polychaete species that burrow are protected within the sediment but the characterizing 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 range of wave exposures experienced by this biotope and similar infralittoral and circalittoral biotopes is considered to indicate, by proxy, that the biotope would have 'High' resistance and by default 'High' resilience to a change in significant wave height at the pressure benchmark. The biotope is therefore classed 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.

The capacity of bivalves to accumulate heavy metals in their tissues, far in excess of environmental levels, is well known. Reactions to sub-lethal levels of heavy metal stressors include siphon retraction, valve closure, inhibition of byssal thread production, disruption of burrowing behaviour, inhibition of respiration, inhibition of filtration rate, inhibition of protein synthesis and suppressed growth (see review by Aberkali & Trueman, 1985). Stirling (1975) investigated the effect of exposure to copper on *Tellina tenuis*. The 96 hour LC₅₀ for Cu was 1000 µg/l. Exposure to Cu concentrations of 250 µg/l and above inhibited burrowing behaviour and would presumably result in greater vulnerability to predators. Similarly, burial of the venerid bivalve, *Venerupis senegalensis*, was inhibited by copper spiked sediments, and at very high concentrations, clams closed up and did not bury at all (Kaschl & Carballeira, 1999). The copper 10 day LC₅₀ for *Venerupis senegalensis* was found to be 88 µg/l in sandy sediments (Kaschl & Carballeira, 1999).

Echinoderms are also regarded as being intolerant of heavy metals (e.g. Bryan, 1984; Kinne, 1984) while polychaetes are tolerant (Bryan, 1984).

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.

Suchanek (1993) reviewed the effects of oil on bivalves. Generally, contact with oil causes an increase in energy expenditure and a decrease in feeding rate, resulting in less energy available for growth and reproduction. Sublethal concentrations of hydrocarbons also reduce byssal thread production (thus weakening attachment) and infaunal burrowing rates. Conan (1982) investigated the long-term effects of the Amoco Cadiz oil spill at St Eflam beach in France. It was estimated that the delayed mortality effects on sand and mud biotas were 1.4 times as large as the immediate effects. *Fabulina fabula* (studied as *Tellina fabula*) started to disappear from the intertidal zone a few months after the spill and from then on was restricted to subtidal levels. In the following 2 years, recruitment of *Fabulina fabula* was very much reduced. The author commented that, in the long-term, the biotas most severely affected by oil spills are low energy sandy and muddy shores, bays and estuaries. In such places, populations of species with long and short-term life expectancies (e.g. *Fabulina fabula*, *Echinocardium cordatum* and *Ampelisca* sp.) either vanished or displayed long-term decline following the Amoco Cadiz oil spill. Polychaetes, however, including *Nephtys hombergii*, cirratulids and capitellids were largely unaffected.

Dauvin (1998) reported the effects of the Amoco Cadiz spill on the fine sand community in the Bay of Morlaix. Reductions in abundance, biomass and production of the community were very evident through the disappearance of the dominant populations of the amphipods *Ampelisca* sp. which are very intolerant of oil contamination. 2 weeks after the spill, the level of hydrocarbons in subtidal sediments reached 200 ppm (Dauvin, 1984; cited in Poggiale & Dauvin, 2001). This caused the disappearance of the *Ampelisca* populations, leaving behind a single species, *Ampelisca sarsi*, in very low densities. The sediment rapidly depolluted and in 1981 benthic recruitment occurred in normal conditions (Dauvin, 1998). However, the recovery of the *Ampelisca* populations took up to

15 years. This was probably due to the amphipods' low fecundity, lack of pelagic larvae and the absence of local unperturbed source populations (Poggiale & Dauvin, 2001).

Echinoderms also seem to be especially intolerant of the toxic effects of oil, probably because of the large amount of exposed epidermis (Suchanek, 1993). The high intolerance of *Echinocardium cordatum* to hydrocarbons was seen by the mass mortality of animals, down to about 20m depth, shortly after the Amoco Cadiz oil spill (Cabioch *et al.*, 1978).

Dauvin (2000) The muddy fine sand *Abra alba*-*Melinna palmata* community from the Bay of Morlaix (western English Channel) was strongly polluted by hydrocarbons from the Amoco Cadiz oil spill in April 1978. Long-term changes of this community (1977-1996) showed that it was weakly affected by the spill. This was due to the low number and low abundance of sensitive species present on the community in normal conditions. Polychaetes, such as *Chaetozone setosa* dominated the community, supporting high levels of organic matter. Only two opportunistic polychaetes *Mediomastus fragilis* and *Tharyx marioni* increased in abundance just after the spill.

Glycera spp. were described by Hiscock *et al.* (2004; 2005, from Levell *et al.*, 1989) as a very tolerant taxa, found in enhanced abundances in the transitional zone along hydrocarbon contamination gradients surrounding oil platforms.

The Braer oil spill in Shetland in 1993 provided an opportunity to identify species that increased or declined in abundance where oiling occurred. Severe weather conditions meant that oil was incorporated into sediments. Kingston *et al.* (1995) noted that the congener *Lumbrineris gracilis* (cited from Hiscock *et al.*, 2004b) declined at oiled sites.

Diaz-Castaneda *et al.* (1989) studied colonization of defaunated and polluted sediments in Dunkerque harbour. The sediment was polluted with both heavy metals and oil. *Capitella capitata* was generally the first polychaete to colonize the polluted sediment. *Spio filicornis* took between 7 weeks and 3 months to appear in the sediment suggesting it is tolerant of oil pollution.

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.

Stirling (1975) investigated the effects of phenol, a non-persistent, semi-synthetic organic pollutant, on *Tellina tenuis*. Exposure to phenol produced a measurable effect on burrowing at all concentrations tested, i.e. 50 mg/l and stronger. Sub-lethal effects of exposure to phenol included delayed burrowing and valve adduction to exclude the pollutant from the mantle cavity. After exposure to 100 mg/l for 24 hours, the majority of animals were extended from their shells and unresponsive to tactile stimulation. Following replacement of the phenol solution with clean seawater, good recovery was exhibited after 2 days for animals exposed to 50 mg/l and some recovery occurred after 4 days for animals exposed to 100 mg/l.

No evidence was found directly relating to the effects of synthetic chemicals on *Magelona mirabilis*. However, there is evidence from other polychaete species. Collier & Pinn (1998) investigated the effect on the benthos of ivermectin, a feed additive treatment for infestations of sea-lice on farmed salmonids. The polychaete *Hediste diversicolor* was particularly susceptible, exhibiting 100% mortality within 14 days when exposed to 8 mg/m³ of ivermectin in a microcosm. *Arenicola marina* was also intolerant of ivermectin through the ingestion of contaminated sediment (Thain *et*

al., 1998; cited in Collier & Pinn, 1998) and it was suggested that deposit feeding was an important route for exposure to toxins. Beaumont *et al.* (1989) investigated the effects of tri-butyl tin (TBT) on benthic organisms. At concentrations of 1-3 µg/l there was no significant effect on the abundance of *Hediste diversicolor* after 9 weeks in a microcosm. However, no juvenile polychaetes were retrieved from the substratum and hence there is some evidence that TBT had an effect on the larval and/or juvenile stages.

Detergents used to disperse oil from the *Torrey Canyon* oil spill caused mass mortalities of *Echinocardium cordatum* (Smith, 1968) and its intolerance to TBT is similar to that of other benthic organisms with LC₅₀ values of 222ng Sn/l in pore water and 1594ng Sn/g dry weight of sediment (Stronkhorst *et al.*, 1999). Gammaridean amphipods have also been reported to be intolerant of TBT with 10 day LC₅₀ values of 1-48 ng/l (Meador *et al.*, 1993).

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

Low

Q: High A: Medium C: NR

High

Q: High A: Low C: Medium

Low

Q: High A: Low C: Low

Riedel *et al.* (2012) assessed the response of benthic macrofauna to hypoxia advancing to anoxia in the Mediterranean. The hypoxic and anoxic conditions were created for 3-4 days in a box that enclosed in-situ sediments. In general molluscs were more resistant than polychaetes, with 90% surviving hypoxia and anoxia, whereas only 10% of polychaetes survived. Exposed individual *Timoclea ovata* and *Tellina serrata* survived the experiment but the exposed *Glycera* spp. died. In general epifauna were more sensitive than infauna, mobile species more sensitive than sedentary species and predatory species more sensitive than suspension and deposit feeders. The test conditions did not lead to the production of hydrogen sulphide which may have reduced mortalities compared to some observations.

Further evidence of sensitivity was available for some of the polychaete species associated with this biotope. Rabalais *et al.* (2001) observed that hypoxic conditions in the north Coast of the Gulf of Mexico (oxygen concentrations from 1.5 to 1 mg/l (1 to 0.7 ml/l) led to the emergence of *Lumbrineris* sp. from the substrate these then lie motionless on the surface. *Glycera alba* was found to be able to tolerate periods of anoxia resulting from inputs of organic rich material from a wood pulp and paper mill in Loch Eil (Scotland) (Blackstock & Barnes, 1982). Nierman *et al.* (1990) reported changes in a fine sand community for the German Bight in an area with regular seasonal hypoxia. In 1983, oxygen levels were exceptionally low (<3 mg O₂/l) in large areas and <1 mg O₂/l in some areas. Species richness decreased by 30-50% and overall biomass fell. *Owenia fusiformis* were reduced in abundance significantly by the hypoxia *Spiophanes bombyx* was found in small numbers at some, but not all areas, during the period of hypoxia. Once oxygen levels returned to normal *Spiophanes bombyx* increased in abundance; the evidence suggests that at least some

individuals would survive hypoxic conditions.

Sensitivity assessment. Riedel *et al.* (2012) provide evidence on general sensitivity trends. The characterizing bivalves are likely to survive hypoxia at the pressure benchmark although the polychaetes present, particularly the mobile predatory species such as *Glycera* and *Nephtys* may be less tolerant. As the biotope is characterized by bivalves and polychaetes, resistance is assessed as 'Low' and resilience as 'High' based on migration, water transport of adults and recolonization by pelagic larvae. Biotope sensitivity is assessed as 'Low'.

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

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

Bivalves, polychaetes and other invertebrate species are unlikely to be directly affected by changes in nutrient enrichment.

Sensitivity assessment. As this biotope is structured by the sediments and water flow rather than nutrient enrichment and is not characterized by macroalgae (although some may be present), the biotope is considered to have 'High' resistance to this pressure and 'High' resilience, (by default) and is assessed as 'Not sensitive'.

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

At the pressure benchmark, organic inputs are likely to represent a food subsidy for the associated deposit feeding species and are unlikely to significantly affect the structure of the biological assemblage or impact the physical habitat. Biotope sensitivity is therefore assessed as 'High' and resilience as 'High' (by default), and the biotope is therefore considered to be 'Not sensitive'.

A Physical Pressures

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

The biotope is characterized by the sedimentary habitat (JNCC, 2015), so 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 bivalves, polychaetes and echinoderms that live buried within the sediment.

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)

Low

Q: High A: High C: High

Very Low

Q: High A: High C: High

High

Q: High A: Low C: Medium

This biotope is found in medium to very fine sand with some silt (JNCC, 2015). The change referred to at the pressure benchmark is a change in sediment classification (based on Long, 2006) rather than a change in the finer-scale original Folk categories (Folk, 1954). For sand sediments, resistance is assessed based on a change to either mixed sediments or mud and sandy muds.

Sediment type is a key factor structuring the biological assemblage present in the biotope. Surveys over sediment gradients and before-and-after impact studies from aggregate extraction sites where sediments have been altered indicate patterns in change. The biotope classification (JNCC, 2015) provides information on the sediment types where biotopes are found and indicates likely patterns in change if the sediment were to alter.

Differences in biotope assemblages in areas of different sediment type are likely to be driven by pre and post recruitment processes. Sediment selectivity by larvae will influence levels of settlement and distribution patterns. Snelgrove *et al.* (1999) demonstrated that *Spisula solidissima*, selected coarse sand over muddy sand, and capitellid polychaetes selected muddy sand over coarse sand, regardless of site. Both larvae selected sediments typical of adult habitats, however, some species were nonselective (Snelgrove *et al.*, 1999) and presumably in unfavourable habitats post recruitment, mortality will result for species that occur in a restricted range of habitats. Some species may, however, be present in a range of sediments. Post-settlement migration and selectivity also occurred on small scales (Snelgrove *et al.*, 1999).

Cooper *et al.* (2011) found that characterizing species from sand dominated sediments were equally likely to be found in gravel dominated sediments, and an increase in sediment coarseness may not result in loss of characterizing species but biotope classification may revert to the biotope SS.SCS.CCS.MedLumVen, which occurs in gravels (JNCC, 2015).

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 *Nephtys cirrosa* dominated the fine sand community. Dominant species of coarse sands, *Echinocyamus pusillus* and *Amphipholis squamata*, were poorly represented and the characteristic species of gravels and shingles were absent (Desprez, 2000).

Sensitivity assessment. A change to finer, muddy and mixed sediments is likely to reduce the abundance of the characterizing *Tellina* spp., venerid bivalves and other bivalves such as *Spisula solida*, and favour polychaetes. Such changes would lead 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: High A: High C: High

Medium

Q: High A: Low C: Medium

Medium

Q: High A: High C: High

Most of the animals that occur in this biotope are shallowly buried and extraction of the sediment will remove the biological assemblage.

Sensitivity assessment. Resistance is assessed as 'None' as extraction of the sediment will 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: Medium C: High

Low

Q: Low A: Low C: Low

Abrasion is likely to damage epifauna and flora and may damage a proportion of the characterizing species, biotope resistance is therefore assessed as 'Medium'. Resilience is assessed as 'High' as opportunistic species are likely to recruit rapidly and some damaged characterizing species may recover or recolonize. Biotope sensitivity is assessed as 'Low'.

Penetration or disturbance of the substratum subsurface**Medium**

Q: High A: High C: Medium

High

Q: High A: Medium C: High

Low

Q: High A: High C: Medium

The epifauna and infaunal assemblages of both stable and dynamic fine sands are susceptible to direct physical disturbance from towed demersal gears and dredges which penetrate and disturb the sediment e.g. Eleftheriou & Robertson 1992; Kaiser *et al.*, 1998; Robinson & Richardson, 1998; Schwinghamer *et al.*, 1996; Freese *et al.*, 1999; Prena *et al.*, 1999; Bergman & Van Santbrink 2000a,b; Tuck *et al.*, 2000; Kenchington *et al.*, 2001; Gilkinson *et al.*, 2005). In general, fishing using towed gears results in the mortality of non-target organisms either through physical damage inflicted by the passage of the trawl or indirectly by disturbance, damage, exposure and subsequent predation. Beam trawling, for example, decreases the density of common echinoderms, polychaetes and molluscs (Bergman & Hup, 1992) and decreases the density and diversity of epifauna in stable sand habitats (Kaiser & Spencer, 1996).

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.

Larger, fragile species are more likely to be damaged by sediment penetration and disturbance than smaller species (Tillin *et al.*, 2006). Bergman & van Santbrink (2000) suggested that the megafauna were amongst the species most vulnerable to direct mortality due to bottom trawling in sandy sediments. Stomach analysis of fish caught scavenging in the tracks of beam trawls found parts of *Spatangus purpureus* and *Ensis* spp. indicating that these had been damaged and exposed by the trawl (Kaiser & Spencer, 1994a). Capasso *et al.* (2010) compared benthic survey datasets from 1895 and 2007 for an area in the English Channel. Although methodological differences limit direct comparison, the datasets appear to show that large, fragile urchin species including *Echinus esculentus*, *Spatangus purpureus* and *Psammechinus miliaris* and larger bivalves had decreased in abundance. Small, mobile species such as amphipods and small errant and predatory polychaetes (*Nephtys*, *Glycera*, *Lumbrineris*) appeared to have increased (Capasso *et al.*, 2010). The area is subject to beam trawling and scallop dredging and the observed species changes would correspond with predicted changes following physical disturbance. Two small species: *Timoclea ovata* and *Echinocyamus pusillus* had increased in abundance between the two periods.

Sensitivity assessment. The trawling studies and the comparative study by Capasso *et al.* (2010) suggest that the biological assemblage present in this biotope is characterized by species that are 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. The results suggest that a reduction in physical disturbance may lead to the development of a community with larger, more fragile species including large bivalves. 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 and the biotope is likely to still be classified as the same type following disturbance. Biotope sensitivity is therefore assessed as 'Low'.

Changes in suspended solids (water clarity)

Medium

Q: Low A: NR C: NR

High

Q: High A: Low C: Medium

Low

Q: Low A: Low C: Low

A change in turbidity at the pressure benchmark is assessed as an increase from intermediate 10-100 mg/l to medium (100-300 mg/l) and a change to clear (<10 mg/l). An increase or decrease in turbidity may affect primary production in the water column and indirectly alter the availability of phytoplankton food available to species in filter feeding mode. However, phytoplankton will also be transported from distant areas and so the effect of increased turbidity may be mitigated to some extent. According to Widdows *et al.* (1979), growth of filter-feeding bivalves may be impaired at suspended particulate matter (SPM) concentrations >250 mg/l.

Sensitivity assessment. No direct evidence was found to assess impacts on the characterizing and associated species. The characterizing, suspension feeding bivalves are not predicted to be sensitive to decreases in turbidity and may be exposed to, and tolerant of, short-term increases in turbidity following sediment mobilization by storms and other events. An increase in suspended solids, at the pressure benchmark may have negative impacts on growth and fecundity by reducing filter feeding efficiency and imposing costs on clearing. Biotope resistance is assessed as 'Medium' as there may be some shift in the structure of the biological assemblage and resilience is assessed as 'High' (following restoration of typical conditions). Biotope sensitivity is assessed as 'Low'.

Smothering and siltation rate changes (light)

Medium

Q: High A: Medium C: Medium

High

Q: High A: Low C: Medium

Low

Q: High A: Low C: Medium

Addition of fine material will alter the character of this habitat by covering it with a layer of dissimilar sediment and will reduce suitability for the species associated with this feature. Recovery will depend on the rate of sediment mixing or removal of the overburden, either naturally or through human activities. Recovery to a recognisable form of the original biotope will not take place until this has happened. In areas where the local hydrodynamic conditions are unaffected, fine particles will be removed by wave action moderating the impact of this pressure. The rate of habitat restoration would be site-specific and would be influenced by the type of siltation and rate. Long-term or permanent addition of fine particles would lead to re-classification of this biotope type (see physical change pressures). The additions of silts to a *Spisula solida* bed in Waterford Harbour (Republic of Ireland) from earthworks further upstream, for example, reduced the extent of the bed (Fahy *et al.*, 2003). No information was provided on the depth of any deposits.

Most bivalve species are capable of burrowing through sediment to feed, e.g. *Abra alba* are capable of upwardly migrating if lightly buried by additional sediment (Schäfer, 1972, cited in Budd, 2008). There may be an energetic cost expended by species to either re-establish burrow openings, to self-clean feeding apparatus or to move up through the sediment, though this is not likely to be significant. Most animals will be able to reburrow or move up through the sediment within hours or days. Bijkerk (1988, results cited from Essink, 1999) indicated that the maximal overburden through which small bivalves could migrate was 20 cm in sand for *Donax* and approximately 40 cm in mud for *Tellina* sp. and approximately 50 cm in sand. No further information was available on the rates of survivorship or the time taken to reach the surface. Little direct evidence was found to assess the impact of this pressure at the benchmark level. Powilleit *et al.* (2009) studied the response of the polychaete *Nephtys hombergii* to smothering. This species successfully migrated to the surface of 32-41 cm deposited sediment layer of till or sand/till mixture and restored contact with the overlying water. The high escape potential could partly be explained by the heterogeneous texture of the till and sand/till mixture with 'voids'. While crawling upward to the new sediment surfaces burrowing velocities of up to 20 cm/day were recorded for *Nephtys hombergii*. Similarly, Bijkerk (1988, results cited from Essink 1999) indicated that the maximal overburden through which species could migrate was 60 cm through mud for *Nephtys* and 90 cm through sand. No further information was available on the rates of survivorship or the time taken to reach the surface.

Sensitivity assessment. Bivalves and polychaetes and other species are likely to be able to survive short periods under sediments and to reposition. However, as the pressure benchmark refers to fine material, this may be cohesive and species characteristic of sandy habitats may be less adapted to move through this than sands. Biotope resistance is assessed as 'Medium' as some mortality of characterizing and associated species may occur. Biotope resilience is assessed as 'High' and biotope sensitivity is assessed as 'Low'.

Smothering and siltation rate changes (heavy)

Low

Q: High A: Medium C: NR

Medium

Q: High A: Low C: Medium

Medium

Q: High A: Low C: Low

Bijkerk (1988, results cited from Essink, 1999) indicated that the maximal overburden through which small bivalves could migrate was 20 cm in sand for *Donax* and approximately 40 cm in mud for *Tellina* sp. and approximately 50 cm in sand. No further information was available on the rates of survivorship or the time taken to reach the surface.

Sensitivity assessment. The character of the overburden is an important factor determining the degree of vertical migration of buried bivalves. Individuals are more likely to escape from a

covering similar to the sediments in which the species is found than a different type. Resistance is assessed as 'Low' as few individuals are likely to reposition. Resilience is assessed as 'Medium' and sensitivity is assessed as 'Medium'.

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

Electromagnetic changes	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR
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No evidence.

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
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Not relevant. No information was found concerning the intolerance of the biotope or the characterizing species to noise. The siphons of bivalves and palps of polychaetes are likely to detect vibrations and are probably withdrawn as a predator avoidance mechanism. However, it is unlikely that the biotope will be affected by noise or vibrations caused by noise at the level of the benchmark.

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

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
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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
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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
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Not relevant.

	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.

	None	Very Low	High
Introduction or spread of invasive non-indigenous species	Q: Low A: NR C: NR	Q: Low A: NR C: NR	Q: Low A: Low C: Low

Few invasive non-indigenous species may be able to colonize mobile sands, due to the high-levels of sediment disturbance. However, two species may be of concern. The slipper limpet *Crepidula fornicata* may settle on stones in substrates and hard surfaces such as bivalve shells and can sometimes form dense carpets which can smother bivalves and alter the seabed, making the habitat unsuitable for larval settlement. Dense aggregations trap suspended silt, faeces and pseudofaeces altering the benthic habitat. Where slipper limpet stacks are abundant, few other bivalves can live amongst them (Fretter & Graham, 1981; Blanchard, 1997). Muddy and mixed sediments in wave sheltered areas are probably optimal but *Crepidula fornicata* has been recorded from a wide variety of habitats including clean sands and areas subject to moderately strong tidal streams (Blanchard, 1997; De Montaudouin & Sauriau, 1999). Bohn *et al.* (2015) report that in the Milford Haven Waterway (MHW) in south-west Wales, UK, subtidally, highest densities were found in areas of high gravel content (grain sizes 16-256 mm), suggesting that the availability of this substrata type is beneficial for its establishment.

The colonial ascidian *Didemnum vexillum* is present in the UK but appears to be restricted to artificial surfaces such as pontoons, this species may, however, have the potential to colonize and smother offshore gravel habitats. Valentine *et al.*, (2007) describe how *Didemnum* sp. appear to have rapidly colonized gravel areas on the Georges Bank (US/Canada boundary). Colonies can coalesce to form large mats that may cover more than 50% of the seabed in parts. Areas of mobile sand bordered communities of *Didemnum* sp. and these, therefore, do not appear to be suitable habitats (Valentine *et al.*, 2007).

Although not currently established in UK waters, the whelk *Rapana venosa*, may spread to UK habitats from Europe. Both *Rapana venosa* and the introduced oyster drill *Urosalpinx cinerea* both predate on bivalves and could therefore negatively affect the characterizing bivalve species.

Sensitivity assessment. The sediments characterizing this biotope are likely to be too mobile or otherwise unsuitable for most of the recorded invasive non-indigenous species currently recorded in the UK. The slipper limpet may colonize this habitat resulting in habitat change and potentially classification to the biotope which is found in similar habitats SS.SMx.IMx.CreAsAn. *Didemnum* sp. and non-native predatory gastropods may also emerge as a threat to this biotope, although more mobile sands may exclude *Didemnum*. Based on *Crepidula fornicata* biotope resistance is assessed as 'None' and resilience as 'Very low' (as removal of established non-native is unlikely), so that biotope sensitivity is assessed as 'High'.

Introduction of microbial pathogens**Medium**
Q: High A: High C: High**High**
Q: High A: Low C: Medium**Low**
Q: High A: Low C: Medium

No evidence was found for the characterizing polychaete species. Populations of bivalve species may be subject to a variety of diseases and parasites but evidence for the characterizing bivalves is limited. Berilli *et al.* (2000) conducted a parasitological survey of the bivalve *Chamelea gallina* in natural beds of the Adriatic Sea, where anomalous mortalities had been observed in 1997-1999. The occurrence of protozoans belonging to the families Porosporidae, Hemispeiridae and Trichodinidae was recorded. Porosporidae of the genus *Nematopsis*, present with 4 species, showed a prevalence of 100%. The results suggested that severe infections of protozoans of the genus *Nematopsis* could cause respiratory impacts, with a possible role in the decline of the natural banks of *Chamelea gallina* (Berilli *et al.*, 2000).

Bacterial diseases are frequently found in molluscs during their larval stages, but seem to be relatively insignificant in populations of adult animals (López-Flores *et al.*, 2004). This may be due to the primary defence mechanisms of molluscs, phagocytosis and encapsulation, which fight against small-sized pathogens, and whose resistance may be age related (Sinderman, 1990; López-Flores *et al.*, 2004).

Individuals of *Fabulina fabula* from Boulogne-sur-Mer (studied as *Angulus fabula*) were infected with the trematode parasite *Gymnophallus strigatus*, causing erosion of the shell (Giard, 1897, cited in Kinne, 1983).

Sensitivity assessments. Pathogens may cause mortality and there may be a minor decline in species richness or abundance in the biotope. As there is no evidence for mass mortalities of characterizing species that would alter biotope classification biotope resistance is assessed as 'Medium'. Biotope resilience is assessed as 'High' as changes may fall within natural population variability and a recognizable biotope is likely to be present after two years. Biotope sensitivity is therefore assessed as 'Low'.

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

A number of the larger bivalve species that may be associated with this biotope group are targeted by commercial fishers in some parts of their range. These include *Chamelea gallina* (Ballarin *et al.*, 2003); *Spisula solida* (Fahy *et al.*, 2003; Joaquim *et al.*, 2008); *Glycymeris glycymeris* and *Paphia* spp. (Savina & Pouvreau, 2004); *Ensis* spp., *Donax* spp. and *Pharus* spp. (Chícharo *et al.*, 2002). In targeted areas, the populations of fished bivalves may be depleted, for example, fishing has led to declines in *Spisula solida* (Joaquim *et al.*, 2008; Fahy *et al.*, 2003).

Sensitivity assessment. In general dredges that are used to target bivalves are likely to be efficient at removing targeted species. Removal of commercially targeted bivalves may lead to biotope reclassification based on the dominance of polychaetes to a similar biotope. Biotope resistance, based on the characterizing bivalves is assessed as 'Low'. Undersized juveniles may be returned and can re-burrow but are likely to suffer from stress. Targeted removal of adult bivalves within the biotope may allow successful recruitment of juveniles where intra-specific competition for space and food and possibly consumption of larvae has prevented successful spatfall. Some species such as *Glycymeris glycymeris* are characteristic of habitats with low levels of competition and may benefit from removal of other species. Biotope resilience is assessed as 'Medium', as recruitment in

many bivalve species is episodic and unpredictable. Biotope sensitivity is therefore assessed as 'Medium'.

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 adults may support recruitment of juvenile bivalves by reducing competition for space and consumption of larvae.

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, biotope sensitivity is therefore assessed as Low'. Some variability in species recruitment, abundance and composition is natural and therefore a return to a recognizable biotope should occur within 2 years. Repeated chronic removal would, however, impact recovery.

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