Neomysis integer and *Gammarus* spp. in variable salinity infralittoral mobile sand

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

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

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Refereed by This information is not refereed

Summary

UK and Ireland classification

EUNIS 2008	A5.223	*Neomysis integer* and *Gammarus* spp. in fluctuating low salinity infralittoral mobile sand
JNCC 2015	SS.SSa.SSaVS.NintGam	*Neomysis integer* and *Gammarus* spp. in variable salinity infralittoral mobile sand
JNCC 2004	SS.SSa.SSaVS.NintGam	*Neomysis integer* and *Gammarus spp.* in variable salinity infralittoral mobile sand
1997 Biotope	SS.IGS.EstGS.NeoGam	*Neomysis integer* and *Gammarus spp.* in low salinity infralittoral mobile sand

Description

Upper estuary mobile fine muddy sands with very low fluctuating salinity characterized by the mysid shrimp *Neomysis integer* and amphipods of the genus *Gammarus* spp. This habitat has a rather sparse infauna and species such as *Neomysis integer* will most likely be found on the sediment surface or just above it whilst *Gammarus* may be under loose weed, stones or other detritus on the sediment surface. The harsh physicochemical regime imposed by such environmental conditions in the upper estuary leads to a relatively impoverished community but high densities of the mobile, salinity-tolerant, crustaceans can occur. The biotope is found in the transitional zone between freshwater and brackish environments, relying on the decreased freshwater input during the summer for penetration of the brackish species up-stream. As such this biotope may also contain elements of freshwater communities. It may be found in conjunction with SMuVS.LhofTtub, although it lacks appreciable numbers of oligochaetes. The numbers of *Neomysis integer* may fluctuate on a seasonal basis due to high overwinter mortality and the location of this biotope within the estuary may also shift upstream or downstream on a seasonal or yearly basis related in part to the freshwater flow into the estuary, as has been noted in the Humber. (Information from Connor *et al*., 2004; JNCC, 2015).

Depth range

0-5 m, 5-10 m

Additional information

Neomysis integer and *Gammarus salinus* are not benthic species and usually live just above the seabed.

Listed By

- none -

Further information sources

Search on:

G G G JNCC

Habitat review

Ecology

Ecological and functional relationships

In the estuarine environment the highly mobile macrofauna comprises two ecologically distinct groupings: those (mainly invertebrate) species permanently resident within an estuary, and those (mainly vertebrate) species entering estuaries principally to feed at high or low tide, e.g. fish and birds respectively (Barnes, 1974).

- Infralittoral mobile sands provide prey for demersal fishes. Prey especially includes mobile small crustaceans which migrate from the sediment and become available to predators. The mysid shrimp, *Neomysis integer* is important as food for fish, especially for juvenile flounder, *Platichthys flesus*, in the upper parts of estuaries (Costa & Elliott, 1999; Bell, 1990).
- Estuarine biotope complexes may be used by important wintering and passage birds for feeding (Elliot *et al.*, 1998).
- *Neomysis integer* may be parasitized by the third larval stage of the nematode *Thynnascaria adunca* (Astthorsson, 1980). Both *Gammarus salinus* and *Gammarus zaddachi* are important host species for the transmission of fish and bird parasites (Voigt, 1991).
- *Gammarus salinus* has a documented role as a seaweed disperser (Breeman & Hoeksema, 1987). The red seaweed *Rhodochorton purpureum* was able to survive digestion by *Gammarus salinus* and grew in the field from faecal pellets.

Seasonal and longer term change

- The abundance of the important characterizing species may vary according to the season, for instance in the Severn Estuary, *Neomysis integer* overwintered at relatively low densities in comparison to the summer, when brooding females swarmed inshore (Moore *et al.*, 1979).
- Seasonal storm events are likely to change sediment distribution significantly.

Habitat structure and complexity

The habitat is not complex and consists of mobile usually coarse sand. The sand provides shelter for a very small variety of mobile species that live 'loosely' amongst the sand grains, e.g. *Gammarus salinus*. Over the sand the habitat for *Neomysis integer* is the water column, and whether or not sand is important to *Neomysis integer* is not clear.

Productivity

The physical environment of infralittoral mobile sands with strong currents is on the whole too harsh for vegetation to become established. Therefore such environments are less productive with lower levels of organic matter. Microphytobenthos may be supported in the interstices of the sand grains in the uppermost millimetres of illuminated sediments, typically appearing as a subtle brownish or greenish staining (Elliott *et al.*, 1998), whilst macroalgae that have become detached from rocky substrata elsewhere may wash up in the estuary, eventually decomposing and contributing to the energy budget of the system. However, the principle source of production in the estuarine environment is secondary, derived from detritus and allochthonous organic matter, which is utilized by the fauna.

Recruitment processes

Neomysis integer and *Gammarus salinus* are the only two species with significant populations regularly recorded from this biotope. Both species are capable of migration over some distance and therefore colonization by adults from other biotopes is likely to occur.

- *Neomysis integer* reaches maturity within 2 - 3 months of release form the females brood pouch (marsuipum). It breeds between spring and autumn and typically produces three generations per year, two during the summer and one in the autumn which overwinters. In most populations of *Neomysis integer* breeding ceases in winter, with the exception of the population from Loch Etive, Scotland, which bred continuously throughout the year, although at low intensity (Mauchline, 1971). *Neomysis integer* has a lifespan of less than a year.
- *Gammarus salinus* typically produces two generations per year. Mature females were found from late November through to late July and the main reproduction period occurred during the winter (Leineweber, 1985). Juveniles were most numerous from April through to July, and in the warmer months between July and October a relatively stable population was attained. *Gammarus salinus* also has a lifespan of less than a year.

Time for community to reach maturity

Little evidence concerning community development was found. However, it is expected that the community, which consists entirely of swimming species, could establish very rapidly as migration from other populations would occur in addition to any larval recruitment. The length of time for recruitment to occur might be a few hours but 'maturity' would not be expected for several weeks in the case of extensive defaunation of the substratum.

Additional information

No text entered.

Preferences & Distribution

Habitat preferences

Depth Range	0-5 m, 5-10 m
Water clarity preferences	No information
Limiting Nutrients	No information
Salinity preferences	Low (<18 psu), Reduced (18-30 psu)
Physiographic preferences	Enclosed coast / Embayment, Estuary
Biological zone preferences	Infralittoral
Substratum/habitat preferences	Muddy sand
Tidal strength preferences	Strong 3 to 6 knots (1.5-3 m/sec.)
Wave exposure preferences	Very sheltered
Other preferences	Surface veneer of mud may be present at slack water

Additional Information

None

Species composition

Species found especially in this biotope

Rare or scarce species associated with this biotope

-

Additional information

No text entered.

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The biotope SS.SSa.SSaVS.NintGam occurs on upper estuary fine muddy sands with very low fluctuating salinity characterized by the mysid shrimp *Neomysis integer* (see Arndt, 1991) and amphipods of the genus *Gammarus spp*. This habitat has a rather sparse infauna and species such as *Neomysis integer* will most likely be found on the sediment surface or just above it whilst *Gammarus* may be under loose weed, stones or other detritus on the sediment surface. The harsh physicochemical regime imposed by such environmental conditions in the upper estuary leads to a relatively impoverished community but high densities of the mobile, salinity-tolerant, crustaceans can occur. The biotope is found in the transitional zone between freshwater and brackish environments, relying on the decreased freshwater input during the summer for penetration of the brackish species up-stream. As such this biotope may also contain elements of freshwater communities. *Neomysis integer* and *Gammarus salinus* are the only two species with significant populations regularly recorded from this biotope. The characterizing species considered in this sensitivity review are *Neomysis integer* and *Gammarus salinus*. Due to the impoverished community, no other species are reviewed in association with SS.SSa.SSaVS.NintGam, although it is acknowledged where appropriate that freshwater species may occur, as this biotope occurs in the transition zone between freshwater and brackish environments (JNCC, 2015).

Resilience and recovery rates of habitat

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

The amphipod *Gammarus salinus* produces multiple broods per year (a maximum of 5 was observed in Norway by Skadsheim (1984)). Mature females have been found from late November through to late July and the main reproduction period occurred during the winter (Leineweber, 1985). Juveniles were most numerous from April through to July, and in the warmer months, between July and October, a relatively stable population was attained. *Gammarus salinus* also has a lifespan of less than a year. Fertilization is external with sperm being deposited in a brood chamber formed of brood plates that arise from the base of thoracic appendages (Fish & Fish, 1996). The mysid *Neomysis integer* reaches maturity within 2-3 months of release from the female's brood pouch (marsupium). It breeds between spring and autumn and typically produces three generations per year; two during the summer and one in the autumn that overwinters. In most populations of *Neomysis integer* breeding ceases in winter, except for a population from Loch Etive, Scotland, which bred continuously throughout the year, although at low intensity (Mauchline, 1971). *Neomysis integer* has a lifespan of less than a year.

Resilience assessment. As the characterizing species reach maturity within a year and proceed to produce more than one generation, recovery is likely to be rapid. In terms of the species present, the biotope may be recognizable within 1-2 years following defaunation. In addition, JNCC (2015) note that this biotope may shift further up or down the estuary on a seasonal or yearly basis depending on freshwater flow. Therefore, resilience is assessed as **'High'** for all levels of impact (i.e. resistance is 'Medium' to 'None').

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	Medium Q: High A: Medium C: Medium	High Q: High A: High C: High	Low Q: High A: Low C: Medium

The geographic distribution of the species characteristic of the biotope and its sub-biotopes extends south of the British Isles so they are likely to be resistant to an increase in temperature. Infaunal species are probably protected to some extent from the direct effects of short-term increases in temperature by sediment buffering, although increased temperatures may affect infauna indirectly by stimulating increased bacterial activity and increased oxygen consumption.

The amphipod *Gammarus salinus* tolerated a variety of temperature and salinity changes. Furch (1972) exposed *Gammarus salinus* to both constant (8°C, 14°C & 20°C) and fluctuating (daily fluctuations between 8°C to 20°C) temperatures. The species revealed significant differences in heat resistance, which became apparent within 12 hours. *Gammarus salinus* was able to endure long-term exposure (2 to 4 weeks) to fluctuating temperatures, although rapid temperature changes (every hour) were less tolerated than lower temperature fluctuations (every 2 hours). Acute temperature changes may cause additional stress but are unlikely to result in mortality. Recovery from rapid fluctuations was apparent within a matter of hours (Furch, 1972).

Environmental temperature exerts an influence on many of the physiological processes of mysid shrimps (Mauchline, 1980). However, the tolerance of mysid shrimps to changes in environmental temperatures varies between species and, to a lesser extent, between populations of the same species in different environments (Mauchline, 1980). The distribution of *Neomysis integer* extends to the south of the UK and along the Atlantic coast of Spain so the species may be able to tolerate a change of 2°C. However, Kinne (1955) found that juveniles of *Neomysis integer* had a different tolerance to temperature changes than adults. Kuhlman (1984) also found that overwintering and summer generations of *Neomysis integer* demonstrated distinct differences to increasing temperature. The upper tolerance of the winter generation was 10-12°C in comparison to 20-25°C for the summer generation. Hence, an acute increase in temperature may be particularly damaging to the population during the spring when the overwintering population commences breeding than at other times of the year. Survival and growth of *Neomysis integer* continued within a temperature range of 8°C to 25°C but sexual maturation was only possible in the narrower range of 15–25°C (Fockeday *et al*., 2005, 2006). *Neomysis integer* is likely to recover within a few weeks or at most six months following summer recruitment and probable migration between suitable habitats.

Sensitivity assessment. Typical surface water temperatures around the UK coast vary, seasonally from 4-19°C (Huthnance, 2010) although in estuaries and other shallow waters the temperature range may exceed this due to summer warming and winter cooling. The biotope, based on the characterizing species, is likely to tolerate a 2°C increase in temperature for a year. *Gammarus salinus* and *Neomysis integer* are likely to be resistant to a chronic change of 2°C for one year but a 5°C increase for one month may impact the *Neomysis integer* population during the spring when the overwintering population commences breeding. Survival and growth of *Neomysis integer* were detected within the whole range tested but sexual maturation was only possible in the narrower range of 15–25°C and 5–15 psu. Therefore, resistance is assessed as **'Medium'**, resilience as **'High'** and sensitivity is assessed as **'Low'.**

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

The distribution of both *Neomysis integer* and *Gammarus salinus* extends to the north of the UK, so the fauna of the biotope would probably be resistant to a long-term decrease in temperature of 2°C. Acute decreases in temperature may cause the death of vulnerable proportions of the population owing to additional stress (e.g. those that are parasitized) but the resistance of healthy individuals is probably high at the benchmark pressure. Survival and growth of *Neomysis integer* continued within a temperature range of 8°C to 25°C, but sexual maturation was only possible in the narrower range of 15–25°C (Fockeday *et al*. 2005, 2006). Reproduction and longer-term abundance of the population may be impacted at the pressure benchmark, particularly in higher latitudes where winter water temperatures would fall below the lower limits of growth and sexual maturation.

Sensitivity assessment. Typical surface water temperatures around the UK coast vary, seasonally from 6-19°C (Huthnance, 2010). Based on the characterizing species, the assessed biotope is considered to be tolerant of a 2°C decrease in temperature for a year, a 5°C decrease for one month is likely to cause some mortality to vulnerable portions of the *Neomysis integer* and *Gammarus salinus* populations. Therefore, resistance to an acute decrease in temperature at the pressure benchmark level is assessed as '**Low**', resilience as '**High**' and sensitivity is assessed as '**Low**'.

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

Salinity is a key factor structuring the biotope. This biotope SS.SSa.SSaVS.NintGam occurs at the transition between freshwater and brackish habitats (JNCC, 2015). Furthermore, JNCC (2015) note that this biotope may shift further up or down the estuary on a seasonal or yearly basis depending on freshwater flow. *Neomysis integer* and *Gammarus salinus* are euryhaline species. However, whilst *Gammarus salinus* may tolerate salinities of 30 psu, *Neomysis integer* was found to have an upper salinity tolerance between 20-25 psu, with death occurring at 30 psu (Kuhlman, 1984) and in the Severn estuary, UK, they were shown to occur in low salinities (Bamber & Henderson, 1994).

Sensitivity assessment. An increase in salinity from 'low' to 'reduced' or 'reduced' to 'full' would probably reduce the abundance of *Neomysis integer* and allow other species to colonize the biotope. For example, the SS.SSa.SSaVS.NintGam habitat may become more like the sub-biotope SS.SSa.SSaVS.NcirLim or the biotope SS.SSa.SSaVS. However, the observation that the SS.SSa.SSaVS.NintGam habitat shifts further up or down the estuary depending on freshwater flow indicates that recovery would be rapid. Therefore, resistance is assessed as '**None**' (as the biotope may be lost within the affected area) but with a resilience of '**High**' so that sensitivity is assessed as '**Medium**'.

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

Salinity is a key factor structuring the biotope. This biotope SS.SSa.SSaVS.NintGam occurs at the transition between freshwater and brackish habitats (JNCC, 2015). Furthermore, JNCC (2015) note that this biotope may shift further up or down the estuary on a seasonal or yearly basis depending on freshwater flow. *Neomysis integer* is tolerant of salinities as low as 0.5 psu (Koepke & Kausch, 1996) and occurs in upper estuary low salinity areas in the Severn estuary UK (Bamber & Henderson, 1994). *Gammarus salinus* is a euryhaline species relatively tolerant of salinities as low as 2 psu and as high as 30 psu, but it is most abundant at 10 psu. Bulnheim (1984) recorded the respiratory response of *Gammarus salinus* in response to an acute salinity change, from 30 psu to 10 psu. Respiration rate moderately increased after an initial shock-like response and initially, specimens were quiescent as they acclimated to the decreased salinity but recovered within 24 hours. Their resistance is likely to be high and recovery immediate.

Sensitivity assessment. A further reduction in salinity at the extreme of their salinity tolerance range would expose them to freshwater. *Neomysis integer* successfully made the transition to freshwater environments but presumably over an extended period. Freshwater species may successfully penetrate the biotope and the SS.SSa.SSaVS.NintGam biotope would temporarily not be recognised. However, the observation that the SS.SSa.SSaVS.NintGam habitat shifts further up or down the estuary depending on freshwater flow indicates that recovery would be rapid. Therefore, resistance is assessed as '**None**' (as the biotope may be lost within the affected area) but with a resilience of '**High**' so that sensitivity is assessed as '**Medium**'.

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

The biotope SS.SSa.SSaVS.NintGam is characterized by strong tidal streams (JNCC, 2015). *Neomysis integer* actively seeks regions where the water flow rate does not in exceed 0.2 knots (10 cm/sec) such as at the waters edge or boundary layer. If exposed to a significant increase in water flow the species present in the biotope would probably experience difficulty in maintaining a position and be washed from the biotope. Sand is also likely to be swept away by increased tidal flow. In the absence of the important characterizing species, the biotope would not be recognised. On resumption of a normal flow regime, the species lost will probably recolonize rapidly from adjacent areas. Spooner (1947) stated that species of *Gammarus* are relatively indifferent to the nature of the substratum to a remarkable degree, provided that there is some kind of object to provide them with shelter/cover. However, an increase in the water flow rate would increase scour which, over a longer period may create the problem of retaining a position in the estuarine environment, against conditions of net seaward transport.

Sensitivity assessment. The biotope is characterized by fine muddy sands in strong water movement caused by tidal streams. SS.SSa.SSaVS.NintGam occurs in areas of strong tidal streams (1.5-3 m/s) (sheltered from wave action) so that the benchmark level of change (0.1-0.2 m/s) is probably insignificant. Hence, the resistance of SS.SSa.SSaVS.NintGam is assessed as '**High**', resilience as '**High**' (by default) and sensitivity assessed as '**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

Not relevant as the biotope occurs in depths of 0-10 m. Owing to the infaunal habit and/or mobility, the characterizing species are likely to be offered considerable protection or would move away to seek more favourable conditions if the limit of the biotope became intertidal.

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

The biotope SS.SSa.SSaVS.NintGam is characterized by strong tidal streams but sheltered from wave action (JNCC, 2015). Increased wave action causes stress to the infauna by disrupting feeding and burrowing. Wave action is also important subtidally in shallower areas as it can disturb the sediment, particularly during storms. Disturbances of this nature may affect shallow and deep sandbanks (Perkins, 1974) and may result in large scale sediment transport. Storm activities reduce species richness, abundance and biomass.

Sensitivity assessment. The biotope SS.SSa.SSaVS.NintGam is 'very sheltered' from wave action (JNCC, 2015). A significant increase in wave exposure is likely to mobilize the sediment and decrease the fine mud component in favour of sands or, in extreme cases, coarse sediment. If the salinity remains 'low' then the characteristic species may remain, but the biotope may change to SS.SSa.SSaVS.MoSaVS, or in extreme cases SS.SCS.SCSVS. However, a 3-5% change in significant wave height (the benchmark) is unlikely to be significant. Therefore, the resistance of SS.SSa.SSaVS.NintGam is assessed as '**High**', resilience as '**High**' (by default) and sensitivity assessed as '**Not Sensitive'.**

Chemical Pressures

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

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

Levels of contaminants that exceed the pressure benchmark may cause impacts. For most metals, toxicity to crustaceans increases with decreased salinity and elevated temperature, therefore marine species living within their normal salinity range may be less susceptible to heavy metal pollution than those living in salinities near the lower limit of their salinity tolerance (McLusky *et al*., 1986). Jones (1973; 1975b) found that mercury (Hg) and copper (Cu) reacted synergistically with changes in salinity and increased temperature (10°C) to become increasingly toxic to species of isopod, including *Eurydice pulchra*. The sediment grade and the hydrographic conditions within the biotope are responsible for high dispersion so that instances of severe pollution are less in comparison to regions with weaker tidal flow. Bryan & Gibbs (1983) reported lower sediment-metal concentrations in sandy areas than mud near the mouth of Restronguet Creek, a branch of the Fal Estuary system which is heavily contaminated with metals.

Although heavy metals may not accumulate in the substratum to the extent that they would in muddy substrata, characterizing infauna are likely to be susceptible. Bryan & Gibbs (1983) suggested that in populations of polychaetes exposed to heavy metal contamination for a long period, metal resistance could be acquired. For example *Nephtys hombergii* from Restronguet Creek seemed able to regulate copper. The head end of the worm became blackened and x-ray microanalysis by Bryan & Gibbs (1983) indicated that this was caused by the deposition of copper sulphide in the body wall. In the same study, Bryan & Gibbs (1983) presented evidence that *Nephtys hombergii* from Restronguet Creek possessed increased tolerance to copper contamination. Specimens from the Tamar Estuary had a 96 h LC50 of 250 µg/l, whilst those from

Restronguet Creek had a 96 h LC50 of 700 µg/l (35 psu; 13°C).

For most metals, toxicity to crustaceans increases with decreased salinity and elevated temperature. Consequently, amphipod species living within their normal salinity range may be less susceptible to heavy metal pollution than those living in salinities near the lower limit of their salinity tolerance (McLusky *et al.*, 1986). Amphipod species characterizing the variations of the biotope in transition zones between freshwater and brackish environments are thereby, likely to suffer greater impacts from contamination. The infaunal population of polychaetes may be intolerant of pulses of heavy metals in solution entering the biotope, as in the absence of mud and silts in combination with the highly dispersive hydrographic regime, concentrations in the substratum are likely to be low and populations do not develop resistance. Whilst many individuals may survive by escaping from the vicinity, some mortality would be expected and defaunation of the sediment may occur.

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 any evidence is presented where available.

Contamination at levels greater than the pressure benchmark may adversely influence the biotope. Suchanek (1993) reviewed the effects of oil spills on marine invertebrates and concluded that, in general, on soft sediment habitats, infaunal polychaetes, bivalves and amphipods were particularly affected. Oil spills resulting from tanker accidents have caused deterioration of sandy communities in the intertidal and shallow sublittoral. Subtidal sediments, however, may be at less risk from oil spills unless oil dispersants are used, or if wave action causes dispersion of oil into the water column and sediment mobility drives oil into the sediment (Elliott *et al.*, 1998). Microbial degradation of the oil within the sediment would increase the biological oxygen demand and oxygen within the sediment may become significantly reduced.

Species within the biotope have been reported to be intolerant of oil pollution, e.g. amphipods (Suchanek, 1993). After the *Amoco Cadiz* oil spill, there was a reduction in both the number of amphipod species and the number of individuals (Cabioch *et al.*, 1978). Initially, significant mortality would be expected, attributable to toxicity. Amphipod populations have been reported not return to pre-spill abundances for five or more years, which is most likely related to the persistence of oil within sediments (Southward, 1982). *Nephtys* species were amongst the fauna that was eradicated from sediments following the 1969 West Falmouth spill of Grade 2 diesel fuel documented by Sanders (1978).

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

Synthetic compound contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

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

No evidence concerning the specific effects of chemical contaminants on *Nephtys* species was found. Boon *et al.* (1985) reported that *Nephtys* species in the North Sea accumulated organochlorines but, based on total sediment analyses, organochlorine concentrations in *Nephtys* species were not correlated with the concentrations in the (type of) sediment which they inhabited.

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

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

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

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

This pressure is **Not assessed**.

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

This biotope is characterized by fine muddy sands in strong water flow, which would probably mitigate areas of reduced or low oxygen concentration. Also, the species characterizing the biotope are mobile and able to migrate vertically to escape unsuitable conditions. Therefore, biotope resistance is assessed as '**High**', and resilience as '**High'** (by default) so that the biotope is assessed as '**Not sensitive'** at the benchmark level.

Nutrient enrichment	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive 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 benchmark is set at compliance with WFD criteria for good status, based on nitrogen concentration (UKTAG, 2014).

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

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

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

The biotope occurs in muddy sand sediments in strong water flow. In-situ primary production is restricted to microphytobenthos although sediment mobility may restrict production levels (Delgado *et al*., 1991). At the pressure benchmark organic inputs are likely to represent a food subsidy for the characterizing amphipods and mysids and are unlikely to significantly affect the structure of the biological assemblage or impact the physical habitat. Therefore, biotope sensitivity is assessed as **'High**' and resilience as '**High'** (by default) so that the biotope is considered to be '**Not sensitive'.**

Physical Pressures

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

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

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

This biotope is only found in the upper reaches of marine inlets, especially estuaries, in fine muddy sands where tidal streams are strong (JNCC, 2015). If the substratum type was changed to either a soft rock or hard artificial type the biotope would be lost altogether.

Sensitivity assessment. The resistance to this change is '**None**', and the resilience is assessed as '**Very low'** as the effect of the pressure is permanent. Therefore, 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 SS.SSa.SSaVS.NintGam biotope is characterized by fine muddy sand. A change in 1 Folk class would result in a change to either i) muds ii) clean sands or iii) gravelly sands and muds. *Gammarus spp.* are present on a wide range of substratum, independent of sediment size and composition, provided the environment is sheltered and there is organic detritus upon which to feed (MES, 2010). Increases in mud or gravel content are unlikely to impact *Gammarus spp.* Similarly, *Neomysis integer* is free-swimming and not dependent on the substratum type.

Sensitivity assessment. However, a change in Folk class to either 'muds' 'clean sands' or to 'gravelly sands' would change the classification of the biotope from SS.SSa.SSaVS to SS.SMuVS or SS.SCS.SCSVS respectively, and the diversity of species would also change so that and the biotope under assessment would be effectively lost. Therefore, the resistance to this change is '**None**', and the resilience is assessed as '**Very low'** as the effect of the pressure 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

The process of extraction is considered to remove all biological components of the biotope. If extraction occurred across the entire biotope, loss of the biotope would occur. Recovery would require substratum to return to sand and with fine silt fraction. *Gammarus spp.* are present on a wide range of substratum, independent of sediment size and composition, provided the environment is sheltered and there is organic detritus upon which to feed (MES, 2010). Although the population present at the time of extraction will be removed, recovery is likely to be rapid. The resistance of the biotope to extraction is assessed as **'None'** but resilience is assessed as '**High**' and biotope sensitivity as '**Medium**'.

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

The mean response of infauna and epifauna communities to fishing activities is shown to be more negative in mud and sand communities than other habitats (Collie *et al*., 2000). Abrasion and compaction of the surficial layer may damage individuals. However, both of the characteristic species, *Neomysis integer* and *Gammarus* sp., are small and highly mobile species that will either avoid or pass through most commercial gears, although some damage or mortalities may occur. For example, *Neomysis integer* is particularly susceptible to injury during collection, causing atypical morphology, which may lead to misidentification (Hayward & Ryland, 1995b). Therefore, resistance is assessed as **'Medium'**, as abrasion is unlikely to affect high numbers of the characterizing species. Resilience is assessed as **'High'** and biotope sensitivity is assessed as **'Low'.**

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

The mean response of infauna and epifauna communities to fishing activities is shown to be more negative in mud and sand communities than other habitats (Collie *et al*., 2000). Abrasion and compaction of the surficial layer may damage individuals. However, both of the characteristic species, *Neomysis integer* and *Gammarus* sp., are small and highly mobile species that will either avoid or pass through most commercial gears, although some damage or mortalities may occur. For example, *Neomysis integer* is particularly susceptible to injury during collection, causing atypical morphology, which may lead to misidentification (Hayward & Ryland, 1995b). Therefore, resistance is assessed as **'Medium'**, as abrasion is unlikely to affect high numbers of the characterizing species. Resilience is assessed as **'High'** and biotope sensitivity is assessed as **'Low'.**

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

This biotope is recorded from estuaries, which are naturally turbid systems due to sediment resuspension by wave and tide action and inputs of high levels of suspended solids, transported by rivers. The level of suspended solids depends on a variety of factors including substratum type, river flow, tidal height, water velocity, wind reach/speed and depth of water mixing (Parr *et al*. 1998). Transported sediment including silt and organic detritus can become trapped in the system where the river water meets seawater. Dissolved material in the river water flocculates when it comes into contact with the salt wedge pushing its way upriver. These processes result in elevated levels of suspended particulate material with peak levels confined to a discrete region (the turbidity maximum), usually in the upper-middle reaches, which moves up and down the estuary with the tidal ebb and flow. Intertidal mudflats depend on the supply of particulate matter to maintain mudflats and the associated biological community is exposed naturally to relatively high levels of turbidity/particulate matter. For instance, *Neomysis integer* collected from the of the Schelde, Gironde and Elbe estuaries in spring occurred in the maximum turbidity zone (Fockedey *et al*., 2005).

Sensitivity assessment. The biological assemblage characterizing this biotope includes mobile mysids and amphipods *Neomysis integer* and *Gammarus salinus*. Increased suspended solids are unlikely to have an impact on theses species. However, a reduction in suspended solids may reduce deposition and supply of organic matter, and a shift between deposition and erosion could result in a net loss of surficial sediments. A reduction in organic matter as suspended solids could also reduce production within this biotope. Therefore, resistance is assessed as '**Medium'** as over a year the impact may be relatively small and resilience is assessed as '**High**', following the restoration of usual conditions. Hence, biotope sensitivity is assessed as '**Low**'.

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

Gammarus spp. are present on a wide range of substrata, independent of sediment size and composition, provided the environment is sheltered and there is organic detritus upon which to feed (MES, 2010). Smothering may cause some mortality to individuals resting on the surface, for instance, *Gammarus salinus* lives in a variety of locations within the estuarine environment:

amongst algae and other vegetation, as well as generally over the sediment surface and beneath stones. It is a mobile species capable of a rapid escape response (backflip) if disturbed, however in the event of suddenly being smothered by up to 5 cm of sediment individuals resting on the surface may be killed. *Neomysis integer* is a free-swimming mysid shrimp, which may rest on the surface of the substratum, but does not live within it and although sufficiently mobile to avoid the deposition of smothering materials, it is possible some individuals will be killed in the event of smothering.

Sensitivity assessment. None of the characterizing species is likely to be significantly impacted by deposition of up to 5 cm of fine material but a small percentage of the characterizing species populations may suffer mortality from smothering, although 5 cm fine sediment is likely to removed within a single tidal cycle. Therefore, resistance is assessed as '**High', r**esilience as '**High'** and sensitivity as '**Not sensitive'** at the benchmark level.

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

Smothering may cause some mortality to individuals resting on the surface, for instance, *Gammarus salinus* lives in a variety of locations within the estuarine environment: amongst algae and other vegetation, as well as generally over the sediment surface and beneath stones. It is a mobile species capable of a rapid escape response (backflip) if disturbed, however in the event of suddenly being smothered by up to 30 cm of sediment individuals resting on the surface may be killed, particularly, if the materials are viscous or impermeable. *Neomysis integer* is a free-swimming mysid shrimp, which may rest on the surface of the substratum, but does not live within it but although sufficiently mobile to avoid the deposition of smothering materials, it is possible some individuals will be killed in the event of smothering. Overall, smothering by 30 cm of fine sediments is likely to result in some mortality of characterizing species, although most are likely to reposition. Therefore, resistance is assessed as **'Medium', r**esilience as '**High,'** and biotope sensitivity is 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

A study of microparticle transfer via planktonic organisms was shown to lead to microplastic intake by *Neomysis integer*. Food web transfer experiments were done by offering zooplankton labelled with ingested microspheres to mysid shrimps. Microscopy observations of mysid intestine showed the presence of zooplankton prey and microspheres after 3 h incubation. *Neomysis integer* showed egestion of microspheres within 12 hr (Setälä *et al*., 2014). Although this study did not examine impacts on health and survivability other studies have shown negative impacts from microplastic ingestion that are likely to impact the food web within this and other biotopes.

The effect of microplastic exposure of the copepod *Centropages typicus* showed that 7.3 m microplastics (>4000 mL−1) significantly decreased algal feeding from experimental studies of exposure to natural assemblages of algae with and without microplastics (Cole *et al*., 2013). These findings imply that marine microplastic debris can negatively impact upon zooplankton function and would potentially limit prey availability to species feeding on *Centropages typicus* such as *Neomysis integer*.

Sensitivity assessment. Overall, the evidence is very limited and assessments cannot be made with confidence and this pressure is **'Not assessed'.**

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

No evidence was found on the effects of electric and magnetic fields on the characterizing species.

Electric and magnetic fields generated by sources such as marine renewable energy device/array cables may alter the behaviour of predators and affect infauna populations. Evidence is limited and occurs for electric and magnetic fields below the benchmark levels, confidence in the evidence of these effects is very low. Field measurements of electric fields at North Hoyle wind farm, North Wales recorded 110µ V/m (Gill *et al.* 2009). Modelled results of magnetic fields from typical subsea electrical cables, such as those used in the renewable energy industry produced magnetic fields of between 7.85 and 20 µT (Gill *et al.* 2009; Normandeau *et al.* 2011). Electric and magnetic fields smaller than those recorded by field measurements or modelled results were shown to create increased movement in thornback ray *Raja clavata* and attraction to the source in catshark *Scyliorhinus canicular* (Gill *et al.* 2009).

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

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

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

Species within the biotope can probably detect vibrations caused by noise. However, at the benchmark level, the community is unlikely to be sensitive to noise and this pressure is '**Not relevant'.**

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

As this feature is not characterized by the presence of primary producers, shading would probably not 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 the 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 *et al.*, 2015). 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 characterizing species could result. Hence, resistance is assessed as '**High'**, resilience as '**High**', and sensitivity is assessed as '**Not sensitive**'.

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

Gammarus spp. and *Neomysis integer* are highly mobile and brood their young so that water transport is not a key method of dispersal over wide distances. Therefore, The biotope (based on the biological assemblage) is considered to have '**High**' resistance to the presence of barriers that lead to a reduction in the 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 may have some, limited, visual perception but as they live in the sediment the species will most probably not be impacted at the pressure benchmark and this pressure is **'Not relevant'.**

Biological Pressures

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

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

Introduction or spread of invasive non-indigenous species	Medium Q: Medium A: Medium C: Medium	Very Low Q: Medium A: Medium C: Medium	Medium Q: Medium A: Medium C: Medium

Limited evidence was available to assess the sensitivity of this biotope. Any invasive species would have to tolerate variable salinity and sediments or mobile sediments that characterizes this biotope group and this will exclude species only able to survive in fully marine conditions and/or that require hard substratum. The North American amphipod *Gammarus tigrinus* was detected in the north-eastern Baltic Sea in 2003 and has rapidly expanded into European waters since (Jänes *et al.*, 2015). Native gammarids, such as *Gammarus salinus* have almost disappeared from some habitats of the northeastern Baltic Sea and the competition for space between the invasive *Gammarus tigrinus* the native *Gammarus salinus* has been a contributing factor in certain habitats

(Kotta *et al.* 2011). Competition for space alone did not explain the mass disappearance of *Gammarus salinus* as *Gammarus tigrinus* did not out-compete *Gammarus salinus* in all Baltic Sea habitats, limiting confidence in the evidence. However, *Gammarus tigrinus* has been identified in many UK estuaries and coasts and appears likely to influence species composition in the biotope (NBN, 2016).

Sensitivity assessment. Limited evidence was available for all characterizing species concerning this pressure. *Gammarus tigrinus* displays faster reproduction and is a voracious predator that is abundant in dilute and more turbid sites. *Gammarus tigrinus* appears to be competitively superior to native gammarids and is likely to alter the species composition of the biotope. In particular the biotope variant SS.SSa.SSaVS.NintGam. The function of the biotope is likely to remain similar however as one gammarid species is likely to be replaced by another but predation rates may change. As the biotope classification is unlikely to change, the resistance of the assessed biotopes is **'Medium'**, resilience is **'Very low'** as the invasive species is unlikely to be removed and its impact is permanent and sensitivity is assessed as **'Medium'**.

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

Gammarus salinus, *Gammarus zaddachi* and *Gammarus oceanicus* were found to be important host species for the transmission of parasites (Voigt, 1991). Larval stages of 4 fish parasites (1 Nematoda, 2 Acanthocephala and 1 Digena) as well as larval stages of 4 bird parasites (1 Nematoda, 1 Acanthocephala, 1 Digena and 1 Cestoda), were reported. However, there was insufficient information concerning the effect that such parasitization may have on the species viability.

Astthorsson (1980) found specimens of *Neomysis integer*, collected from the Ythan Estuary, Scotland, to be parasitized by the third larval stage of the nematode *Thynnascaria adunca*. The nematodes were found in both the thorax and the abdomen, usually coiled. In some instances, the total length of the *Thynnascaria adunca* larvae was almost the same length as the *Neomysis integer* host. Astthorsson (1980) suspected that the larvae would probably have an influence on the internal physiology of the host but there is insufficient information concerning any effect upon the population that such parasitization may have.

Sensitivity assessment. Based on the lack of evidence for mortalities in characterizing species in relation to pathogens, and amphipods hosting parasites, resistance is assessed as '**High**' and resilience as '**High**', by default, so that the biotope is assessed as '**Not sensitive'**. Confidence, however, is low due to the lack of evidence of effects on populations of microbial pathogens.

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

Neither of the characteristic species are subject to targeted recreational or commercial harvesting. Therefore, this pressure is assessed as **'Not relevant'**.

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

Direct, physical impacts are assessed through the abrasion and penetration of the seabed pressures, while this pressure considers the ecological or biological effects of by-catch. Species in this biotope, including the characterizing species, may be damaged or directly removed by static or mobile gears that are targeting other species (see abrasion and penetration pressures). However, both species, *Neomysis integer* and *Gammarus* sp., are small and highly mobile species that will either avoid or pass through most commercial gears, although some damage or mortalities may occur. In addition, the substratum (fine muddy sands) is unlikely to be significantly damaged by passing gear, as the habitat is reported to move up and down the estuary seasonally or annually depending on water flow (JNCC, 2015). Therefore, resistance is assessed as **'Medium',** resilience as **'High'** (as the characteristic fauna and substratum are likely to recover rapidly), and biotope sensitivity as **'Low'.**

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