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

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

Georgina Budd

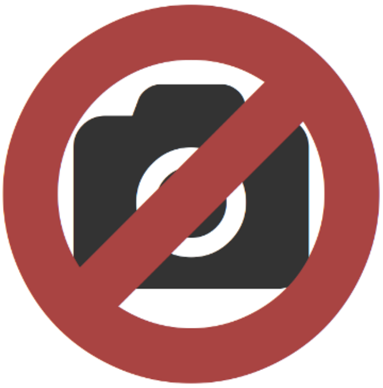
2002-05-24

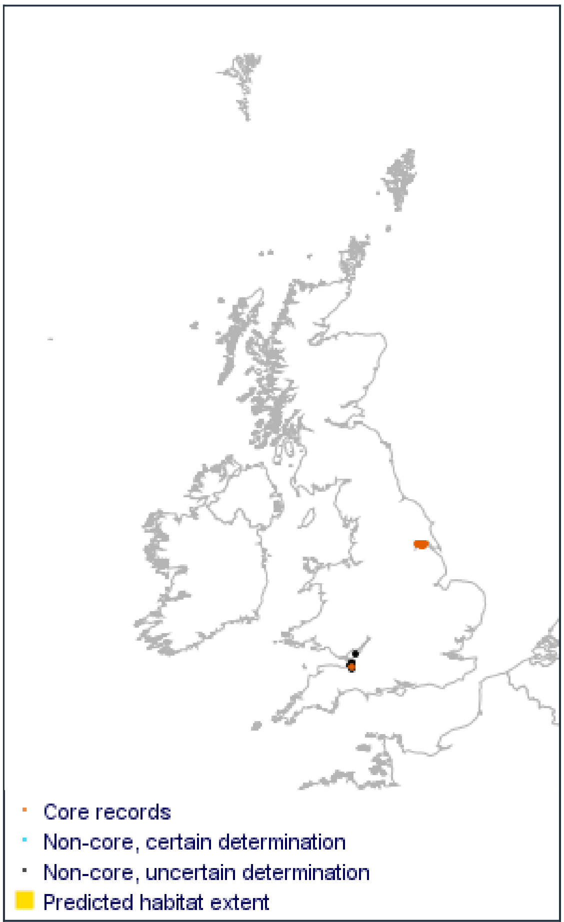
A report from:
The Marine Life Information Network, Marine Biological Association of the United Kingdom.

Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [https://www.marlin.ac.uk/habitats/detail/51]. All terms and the MarESA methodology are outlined on the website (https://www.marlin.ac.uk)

This review can be cited as:
Budd, G.C. 2002. [Neomysis integer] and [Gammarus] spp. in variable salinity infralittoral mobile sand. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom.
DOI https://dx.doi.org/10.17031/marlinhab.51.1

(page left blank)





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

Researched by Georgina Budd **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 sands with very low fluctuating salinity characterized by the mysid shrimp *Neomysis integer* and amphipods of the genus *Gammarus* spp. 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 IMU.LimTtub, although it lacks appreciable numbers of oligochaetes. The biotope occurs in a similar habitat to IGS.MobRS although it is more affected by lower salinity. (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 97.06: Connor *et al.*, 1997a, b).

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	
Limiting Nutrients	No information found
Salinity preferences	Low (<18 psu)
Physiographic preferences	Enclosed coast / Embayment
Biological zone preferences	Infralittoral
Substratum/habitat preferences	Sand
Tidal strength preferences	Moderately Strong 1 to 3 knots (0.5-1.5 m/sec.), Strong 3 to 6 knots (1.5-3 m/sec.)
Wave exposure preferences	Extremely sheltered, Very sheltered
Other preferences	

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

Explanation

*Neomysis integer*and the *Gammarus* species are considered to be important characterizing species of the IGS.NeoGam biotope. The biotope is typically species poor, the species present being robust errant forms, in their absence the biotope would be particularly barren and not necessarily recognised.

Species indicative of sensitivity

Community Importance	Species name	Common Name
Important characterizing	*Gammarus salinus*	A gammarid shrimp
Important characterizing	*Gammarus zaddachi*	A gammarid shrimp
Important characterizing	*Neomysis integer*	Opossum shrimp

Physical Pressures

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Substratum Loss	High	Very high	Low	Decline	Low

The important characterizing species may be relatively unaffected by substratum loss as they are mobile and rest upon the surface as opposed to burrowing into it, so would probably relocate. However, intolerance of the biotope to substratum loss has been assessed to be high owing to the fact that at the benchmark level all of the substratum is removed by an activity such as dredging and in the absence of the sand the biotope would not necessarily be recognized. The biotope should recover assuming that sand is re-deposited, therefore recoverability has been assessed to be very high.

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Smothering	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant

The important characterizing species of the biotope are mobile, able to both swim and crawl and would therefore probably escape smothering. Consequently an intolerance assessment of not relevant has been made.

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Increase in suspended sediment	Tolerant	Not relevant	Not relevant	No change	Moderate

In the estuarine environment the concentration of suspended sediment is typically very high. Increased suspended sediment may bring additional food for *Neomysis integer* which suspension feeds upon phytoplankton and detrital material, although an excess of suspended matter may also have some adverse effects, e.g. clogging feeding structures. However on balance, an assessment of not sensitive at the benchmark level has been suggested.

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Decrease in suspended sediment	Tolerant	Immediate	Not sensitive*	Rise	Low

A decrease in suspended sediment would reduce the detrital food source available to the species, but at the benchmark level a decrease in suspended sediment is not likely to have a detectable effect on survival of the important characterizing species for a period of one month and an assessment of not sensitive has been made.

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Dessication	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant

The biotope is subtidal and therefore desiccation is not relevant.

Increase in emergence regime	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant

The biotope is subtidal and therefore a change in the emergence regime was not considered to be relevant.

Decrease in emergence regime			Not sensitive*	Not relevant	

The biotope is subtidal and therefore a change in the emergence regime was not considered to be relevant.

Increase in water flow rate	High	Very high	Low	Major decline	Moderate

Neomysis integer actively seeks regions where water flow rate is not in excess of 0.2 knots (10 cm/sec) such as at the waters edge or boundary layer. Normally the biotope experiences strong to moderately strong water flow rates and the benchmark increase would expose the community to currents in excess of 6 knots (> 3 m/sec). 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 and intolerance has therefore been assessed to be high. On resumption of a normal flow regime the species that may have been lost will probably recolonize from adjacent areas and recovery has been assessed to be very high assuming suitable substrate is deposited.

Decrease in water flow rate	Tolerant		Not relevant	No change	Low

A decrease in water flow rate, in the absence of wave action determining substratum type would probably favour the accretion of finer silts and clays which, over a period of a year may serve to stabilise the surface sediment and enable the colonization of oligochaetes tolerant of conditions of low fluctuating salinity such as *Limnodrilus hoffmeisteri* and *Tubifex tubifex*. Consequently the biotope may no longer be recognisable and intolerance to a decreased water flow rate has been assessed to be high. Resumption of moderately strong to strong water flow rates would winnow away fine particulate matter that had accumulated and probably suppress the viability of species not normally present in the biotope, therefore recovery is likely to be high.

Increase in temperature	Intermediate	Very high	Low	Decline	Moderate

Specimens of *Gammarus salinus* were tolerant of temperature fluctuations between 8 °C and 20 °C over a period of up to four weeks, acute temperature changes caused additional stress but did not result in mortality (Furch, 1972). The distribution of *Neomysis integer* extends to the south of the UK, along the Atlantic coast of Spain so the species may be able to tolerate a chronic change of 2 °C. However, Kuhlman (1984) found that over-wintering and summer generations of *Neomysis integer* had different upper temperature tolerances. Consequently, an acute increase in temperature may be particularly damaging to the population during the spring when the over-wintering population commences breeding than at other times of the year. Intolerance of the biotope fauna to an acute increase in temperature has been assessed to be intermediate. Recovery of the fauna is likely to be relatively rapid as recruitment will occur within in the year along with migration of the important characterizing species from other adjacent biotopes.

Decrease in temperature	Intermediate	Very high	Low	Decline	Very low

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 tolerant of a chronic decrease in temperature of

2 °C. Acute decreases in temperature may cause death of vulnerable proportions of the population owing to additional stress, e.g. those that are parasitized, and intolerance has been assessed to be intermediate. Recovery of the fauna is likely to be relatively rapid as recruitment will occur within the year along with migration of the important characterizing species from other adjacent biotopes

Increase in turbidity	Tolerant	Not relevant	Not relevant	No change	High

The Humber Estuary, in which the IGS.NeoGam biotope occurs is naturally highly turbid (Uncles *et al.*, 2001). On a spring ebb tide in November 1995 concentrations of surface suspended particulate matter (SPM) were measured to be from 6 in the upper estuary to 13 g per litre at the confluence with the River Ouse which, would drastically reduce light penetration. Consequently, it is unlikely that the benchmark increase in turbidity would be of significance to the fauna and the biotope has been assessed not to be sensitive.

Decrease in turbidity	Tolerant		Not sensitive*	No change	

Estuarine waters such as that of the Humber, in which the IGS.NeoGam biotope occurs, are typically turbid. The benchmark decrease in turbidity is unlikely to be of any significance to the fauna of the biotope and an assessment of not sensitive has been made.

Increase in wave exposure	High	Moderate	Moderate	Major decline	Moderate

The biotope occurs in very sheltered to extremely sheltered locations where tidal flow is normally more important than wave action as a structuring factor. Increased wave exposure would probably result in displacement of the substratum. Over one year, sufficient layers of the substratum might be lost so that the biotope substratum changes to a different one, e.g. exposed rock. The important characterizing species, *Neomysis integer* and *Gammarus* spp. are relatively robust, epibenthic mobile species whose presence in the biotope is not especially determined by the nature of the substratum. However, they both utilize surface features and aggregate at the shallow waters edge in order to seek shelter from faster currents against which they cannot swim. Wave induced turbulence is likely to displace them and they may be washed from the biotope. Owing to the combination of a change in biotope substratum and potential loss of important characterizing species intolerance to increased wave exposure has been assessed to be high as the biotope would not be recognised. The important characterizing species have a very high capacity for recovery but owing to removal of the sandy substratum recovery of the biotope as a whole is likely to take longer and has been assessed to be moderate.

Decrease in wave exposure	Tolerant		Not relevant	No change	Low

The biotope occurs in very sheltered to extremely sheltered locations where tidal flow is probably more important than wave action as a structuring factor. A reduction in wave action is therefore unlikely to have a significant effect. Therefore the biotope has been assessed to be not sensitive.

Noise	Tolerant	Not relevant	Not sensitive	No change	Low

Gammarus spp. and *Neomysis integer* may respond to vibrations caused by noise, but are likely to be not sensitive to noise at the benchmark level.

Visual Presence	Tolerant	Not relevant	Not sensitive	No change	Low

Gammarus spp. and *Neomysis integer* are unlikely to have the visual acuity to detect the presence of for instance boats travelling over the biotope. although, it is likely that they observe predators and react to them. An assessment of visual presence is related to human activity to which the community is considered to be not sensitive.

Abrasion & physical disturbance	Tolerant	Not relevant	Not sensitive	No change	High

Elliot *et al.* (1998) reported that subtidal mobile sand banks were colonized by infaunal or epifaunal small bivalves, crustaceans and polychaetes adapted to a changeable hydrography and substratum. Species living in mobile substrata are able to reburrow quickly after being washed out of the sediment, e.g. *Nephtys cirrhosa* and amphipods. Continual sediment disturbance results in a large number of opportunistic species, e.g. *Chaetozone setosa* (Elliot *et al.*, 1998). Subtidal mobile sandbanks are the result of high energy conditions and naturally disturbed by hydrographic conditions such as storms. Therefore, Elliot *et al.* (1998) suggested that the community is likely to recover from sediment disturbance, since the associated species are predominately mobile, able to tolerate sediment movement, and the influx of sediment from natural or man-made sources (e.g. dredged spoil). For example, Jennings & Kaiser (1998) reported that in experiments in the Irish Sea, the effects of beam trawl disturbance could not be detected in mobile sediments, which was attributed to the levels of natural disturbance in megaripple habitats. Animals living in the troughs of sediment ripples were less likely to be disturbed by since fishing gear rode over the crests of the sand waves (Jennings & Kaiser, 1998). Therefore, an assessment of not sensitive has been recorded.

Displacement	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant

The important characterizing species of the IGS.NeoGam are mobile species, therefore an intolerance assessment for displacement was not considered relevant.

Chemical Pressures

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Synthetic compound contamination	Intermediate	Very high	Low	Decline	High

Estuaries may receive effluent discharges which contain a variety of synthetic chemicals. In general, crustaceans are widely reported to be intolerant of synthetic chemicals (Cole *et al.*, 1999). *Neomysis integer* was found to be intolerant of exposure to the organophosphate pesticide, Chlorpyrifos. Following 7 days of exposure to a concentration of 0.038 µg /l, its swimming behaviour was disrupted, an effect which would compromise the ability of *Neomysis integer* to maintain its position in the estuarine environment (Roast *et al.*, 2000b). In addition, synthetic chemicals have been reported to affect species of *Gammarus* related to *Gammarus salinus*. *Pentachlorophenol (PCP) and benzo[a]pyrene (B[a]P) impaired swimming stamina and disrupted embryo development in Chaetogammarus marinus (Lawrence & Poulter, 2001). Owing to the likelihood of a consequential reduction in abundance and viability of the crustacean populations in the biotope, intolerance has been assessed to be intermediate. The important characterizing species have a very high capacity for recovery assuming degradation of the synthetic contaminants.*

Heavy metal contamination	Intermediate	Very high	Low	Decline	High

The salinity-temperature dependent toxicity of cadmium and other heavy metals to marine and estuarine invertebrates is well documented (reviewed in McLusky *et al.*, 1986). Wildgust & Jones (1998) found that mortalities of *Neomysis integer* resulting from free cadmium ion exposure were greater at salinities of 28 and 12 psu than at 20 psu. However, the swimming behaviour and orientation of *Neomysis integer* was disrupted following exposure to 0.5 µg Cd $_{(aq)}^{2+}$ per litre, a significantly lower cadmium concentration than that causing mortality (Roast *et* *al*., 2000). The significance of this sub-lethal effect is that *Neomysis integer* would be unable to maintain its position within the estuary, resulting in reduced abundance of the population. Similarly, Lawrence & Poulter (2001) observed disrupted embryogenesis and swimming stamina in *Chaetogammarus marinus*, a species related to *Gammarus salinus*. Intolerance of the biotope fauna has been assessed to be intermediate owing to reduced abundance as a result of reduced swimming ability. The important characterizing species have a very high capacity for recovery assuming degradation of the synthetic contaminants.

Hydrocarbon contamination	High	Very high	Low	Major decline	Moderate

Amphipods are generally very sensitive to oil pollution (Suchanek, 1993). Ponat (1975) observed the narcotic effect of crude oil on *Gammarus salinus*, which reduced the species oxygen consumption to 40 % of normal levels. Lindén (1976) also observed narcosis in *Gammarus oceanicus*, a species related to *Gammarus salinus*, exposed to concentrations of oil between 5 to 20 mg /l, which followed an initial period of hectic swimming and then deterioration of crawling ability. Furthermore, sub-lethal concentrations of crude oil (1-40 µg/l) proved to be responsible for a reduction in the numbers of sexually mature adults of *Gammarus oceanicus* entering precopula, a requirement for successful fertilization (Lindén, 1976b). The intolerance of the biotope to hydrocarbon contamination has been assessed to be high owing to the probable destruction of the important characterizing *Gammarus* species.

Radionuclide contamination		Not relevant		Not relevant	Not relevant

Radionuclides can accumulate within substrata. However, there is little information concerning their biological effects (Cole *et al*., 1999).

Changes in nutrient levels	Tolerant*	Not relevant	Not sensitive*	Not relevant	Very low

Primary productivity within in the biotope is extremely limited. Nutrient enrichment at the benchmark level which directly or indirectly enhances the supply of detrital organic material available to the fauna for consumption is likely to be beneficial and an intolerance assessment of not sensitive * has been made.

Increase in salinity	High	Immediate	Very Low	Rise	Low

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). An intolerance assessment of high has been made owing to the fact that the biotope is characterized by species tolerant of lower salinities, increased salinity would cause physiological stress to the important characterizing species and favour the establishment of fully marine species and the IGS.NeoGam biotope would temporarily not be recognised. On return to a brackish water salinity regime, recovery of the important characterizing species has been assessed to be very high owing to immigration and rapid reproduction.

Decrease in salinity	High	Immediate	Moderate	Rise	Low

Neomysis integer is tolerant of salinities as low as 0.5 psu (Koepke & Kausch, 1996) and *Gammarus salinus* can tolerate a salinity of 2 psu. 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 of time. An intolerance assessment of high has been made as freshwater species may successfully penetrate the biotope and the IGS.NeoGam biotope would temporarily not be recognised. On return to a brackish water salinity regime, recovery of the important characterizing species has been assessed to be very high owing to migration and rapid reproduction.

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Changes in oxygenation	High	Immediate	Very Low	Major decline	Moderate

Gammarus salinus demonstrated negative rheotaxis (swimming away) in response to a current of sub-lethal and lethal concentrations of oxygen (Vobis, 1973). It is also probable that as a mobile species *Neomysis integer* would also avoid decreased oxygen concentrations to which it is intolerant. Consequently, in the absence of the important characterizing species the biotope would temporarily not be recognized and intolerance has been assessed to be high. On return to prior conditions, repopulation is likely to occur rapidly as the species move into feed.

Biological Pressures

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Introduction of microbial pathogens/parasites		Not relevant		Not relevant	Not relevant

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).

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Introduction of non-native species		Not relevant		Not relevant	Not relevant

No information concerning non-native species that might affect the abundance or survival of the important characterizing species of the IGS.NeoGam biotope was found.

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Extraction of this species	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant

It is extremely unlikely that any of the species indicative of sensitivity would be targeted for extraction and we have no evidence for the indirect effects of extraction of other species on this biotope.

	Intolerance	Recoverability	Sensitivity	Richness	Confidence
Extraction of other species	Not relevant	Not relevant	Not relevant	Not relevant	Not relevant

Additional information

Recoverability

No 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. Recoverability has therefore been assessed to be very high in general.

Bibliography

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

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

Attrill, M.J., 1990. *The Thames estuary benthic programme: a site by site report of the quarterly macrofauna surveys April 1989 - March 1990.* , Unpublished, National Rivers Authority, Thames Region Biology Report.

Bell, A.A., 1990. Population structure, feeding habits and parasites of flounder, *Platichthys flesus* L. in the upper Forth estuary. , BSc Hons. thesis, University of Stirling. 97pp.

Breeman, A.M. & Hoeksema, B.W., 1987. Vegetative propagation of the red alga *Rhodochorton purpureum* by means of fragments that escape digestion by herbivores. *Marine Ecology Progress Series*, **35**, 197-201.

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

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

Costa, M.J. & Elliot, M., 1991. Fish usage and feeding in two industrialised estuaries - the Tagus, Portugal and the Forth, Scotland. In *Estuaries and Coasts: Spatial and Temporal Intercomparisons* (ed. B. Knights & A.J. Phillips), pp. 289-297. Denmark: Olsen & Olsen.

Dalkin, M.J., Gudmundsson, H. & Barnett, B., 1996. *HEC grid survey 1995 (Subtidal benthic survey- quinquennial classification).* , Environment Agency, Lincoln.

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

Elliot, M., Nedwell, S., Jones, N.V., Read, S.J., Cutts, N.D. & Hemingway, K.L., 1998. Intertidal sand and mudflats & subtidal mobile sandbanks (Vol. II). An overview of dynamic and sensitivity for conservation management of marine SACs. *Prepared by the Scottish Association for Marine Science for the UK Marine SACs Project.*

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

Jennings, S. & Kaiser, M.J., 1998. The effects of fishing on marine ecosystems. *Advances in Marine Biology*, **34**, 201-352.

JNCC, 2015. The Marine Habitat Classification for Britain and Ireland Version 15.03. (20/05/2015). Available from https://mhc.jncc.gov.uk/

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

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

Lawrence, A.J. & Poulter, C., 2001. Impact of copper, pentachlorophenol and benzo[a]pyrene on the swimming efficiency and embryogenesis of the amphipod *Chaetogammarus marinus*. *Marine Ecology Progress Series*, **223**, 213-223.

Lawrie, S.M, Speirs, D.C., Raffaelli, D.G., Gurney, W.S.C., Paterson, D.M. & Ford, R., 1999. The swimming behaviour and distribution of *Neomysis integer* in relation to tidal flow. *Journal of Experimental Marine Biology and Ecology*, **242**, 95-106.

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

Lindén, O., 1976. Effects of oil on the amphipod *Gammarus oceanicus*. *Environmental Pollution*, **10**, 239-250.

Lindén, O., 1976b. Effects of oil on the reproduction of the amphipod *Gammarus oceanicus*. *Ambio*, **5**, 36-37.

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

McLusky, D.S., Bryant, V. & Campbell, R., 1986. The effects of temperature and salinity on the toxicity of heavy metals to marine and estuarine invertebrates. *Oceanography and Marine Biology: an Annual Review*, **24**, 481-520.

Ponat, A., 1975. Investigations on the influence of crude oil on the survival and oxygen consumption of *Idotea baltica* and *Gammarus salinus*. *Kieler Meeresforschungen*, **31**, 26-31.

Roast, S.D., Widdows, J. & Jones, M.B., 2000. Mysids and trace metals: disruption of swimming as a behavioural indicator of environmental contamination. *Marine Environmental Research*, **50**, 107-112.

Roast, S.D., Widdows, J. & Jones, M.B., 2000b. Disruption of swimming in the hyperbenthic mysid *Neomysis integer* (Peracarida: Mysidacea) by the organophosphate pesticide chlorpyrifos. *Aquatic Toxicology*, **47**, 227-241.

Suchanek, T.H., 1993. Oil impacts on marine invertebrate populations and communities. *American Zoologist*, **33**, 510-523.

Uncles, R.J., Lavender, S.J. & Stephens, J.A., 2001. Remotely sensed observations of the turbidity maximum in the highly turbid Humber estuary, UK. *Estuaries*, **24**, 745-755.

Vobis, H., 1973. Rheotactic behaviour of some *Gammarus* species in different oxygen concentrations of the water. *Helgolander Wissenschaftliche Meeresuntersuchungen*, **25**, 495-508.

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

Wildgust, M.A. & Jones, M.B., 1998. Salinity change and the toxicity of the free cadmium ion [$Cd^{2+}_{(aq)}$] to *Neomysis integer* (Crustacea: Mysidacea). *Aquatic Toxicology*, **41**, 187-192.