Venerupis corrugata, *Amphipholis squamata* and *Apseudes holthuisi* in infralittoral mixed sediment

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

Dr Heidi Tillin & Will Rayment

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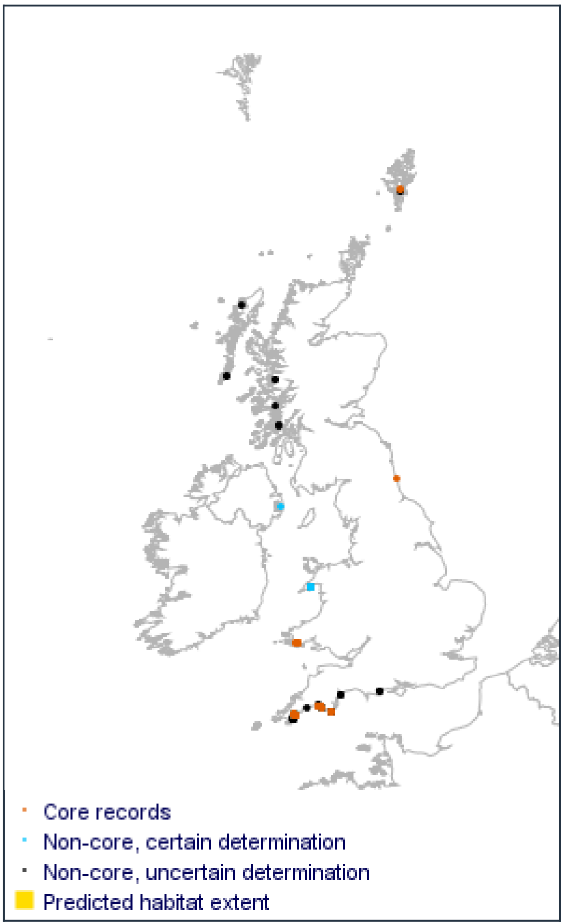

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Dr Heidi Tillin & Will Rayment **Refereed by** This information is not refereed.

Summary

UK and Ireland classification

EUNIS 2008	A5.433	*Venerupis senegalensis*, *Amphipholis squamata* and *Apseudes latreilli* in infralittoral mixed sediment
JNCC 2015	SS.SMx.IMx.VcorAsquAps	*Venerupis corrugata*, *Amphipholis squamata* and *Apseudes holthuisi* in infralittoral mixed sediment
JNCC 2004	SS.SMx.IMx.VsenAsquAps	*Venerupis senegalensis*, *Amphipholis squamata* and *Apseudes latreilli* in infralittoral mixed sediment
1997 Biotope	SS.IMX.FaMx.VsenMtru	*Venerupis senegalensis* and *Mya truncata* in lower shore or infralittoral muddy gravel

Description

Sheltered muddy sandy gravel and pebbles in marine inlets, estuaries or embayments with variable salinity or fully marine conditions, support large populations of the pullet carpet shell *Venerupis* *senegalensis* with the brittlestar *Amphipholis squamata* and the tanaid *Apseudes latreilli*. This biotope may be found at a range of depths from 5m to 30m although populations of *Venerupis senegalensis* may also be found on the low shore. Other common species within this biotope include the gastropod *Calyptraea chinensis*, a range of amphipod crustacea such as *Corophium sextonae* and *Maera grossimana* and polychaetes such as *Mediomastus fragilis*, *Melinna palmata*, *Aphelochaeta marioni*, Syllids and tubificid oligochaetes. Many of the available records for this biotope are from southern inlets and estuaries such as Plymouth Sound and Milford Haven but *Venerupis senegalensis* has a much wider distribution and it should be noted that northern versions of this biotope may a have a much lower species diversity (JNCC, 2015).

Depth range

0-5 m, 5-10 m, 10-20 m, 20-30 m

Additional information

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Listed By

- none -

Further information sources

Search on:

G G JNCC

Habitat review

Ecology

Ecological and functional relationships

- The species composition of the biotope is probably determined largely by the substratum characteristics and therefore the hydrodynamic regime and sediment supply, rather than the interspecific relationships. Sediment is the most extensive sub-habitat within the biotope and hence infauna dominate.
- The suspension feeding infaunal bivalves, e.g. *Venerupis senegalensis*, *Abra alba*, *Kurtiella bidentata* and *Mya truncata*, compete for nutrients among themselves and with epifauna, e.g. *Mytilus edulis*.
- Spatial competition probably occurs between infaunal suspension feeders and deposit feeders. Reworking of sediment by deposit feeders, e.g. *Arenicola marina*, makes the substratum less stable, increases the suspended sediment and makes the environment less suitable for suspension feeders (Rhoads & Young, 1970). Tube building, e.g. by *Lanice conchilega*, and byssal attachment, e.g. by *Venerupis senegalensis*, stabilize the sediment and arrest the shift towards a community dominated by deposit feeders.
- Amphipods, e.g. *Corophium* sp., and the infaunal annelid species in this biotope probably interfere strongly with each other. Adult worms probably reduce amphipod numbers by disturbing their burrows, while high densities of amphipods can prevent establishment of worms by consuming larvae and juveniles (Olafsson & Persson, 1986). *Arenicola marina* has been shown to have a strong negative effect on *Corophium volutator* due to reworking of sediment causing the amphipod to emigrate (Flach, 1992).
- *Carcinus maenas* is a significant predator in the biotope. It has been shown to reduce the density of *Mya arenaria*, *Cerastoderma edule*, *Abra alba*, *Tubificoides benedii*, *Aphelochaeta marioni* and *Corophium volutator* (Reise, 1985). A population of *Carcinus maenas* from a Scottish sea-loch preyed predominantly on annelids (85% frequency of occurrence in captured crabs) and less so on molluscs (18%) and crustaceans (18%) (Feder & Pearson, 1988).
- Carnivorous annelids such as *Nephtys hombergii* and *Pholoe inornata* operate at the trophic level below *Carcinus maenas* (Reise, 1985). They predate the smaller annelids and crustaceans.
- *Cerastoderma edule* and *Mya arenaria* are common prey for several bird species. *Ensis* sp. and *Venerupis* sp. are also heavily predated (Meire, 1993). The main bird predator in the biotope is probably the oystercatcher, *Haematopus ostralegus*. Drianan (1957, cited in Meire, 1993) estimated that oystercatchers remove 22% of the cockle population annually in Morecambe Bay. It should be noted that only the upper portion of the biotope will be vulnerable to predation by shore birds at low tide.
- Macroalgae, e.g. *Fucus serratus*, colonize the hard substrata where present. The low energy environment allows colonization of gravel and pebbles which in higher energy environments would be too unstable.
- *Littorina littorea* and *Steromphala cineraria* graze microalgae and ephemeral green algae, preventing domination by the faster growing species. Calcareous species, e.g. the Corallinaceae, are resistant to grazing.

Seasonal and longer term change

Seasonal changes occur in the abundance of the fauna due to seasonal recruitment processes.

Venerupis senegalensis exhibits pronounced year class variability in abundance (Johannessen, 1973b; Perez Camacho, 1980) probably due to patchy recruitment and/or variable post recruitment processes. Variation in abundance is very pronounced in the polychaete *Aphelochaeta marioni*. In the Wadden Sea, peak abundance occurred in January (71,200 individuals per m^2) and minimum abundance occurred in July (22,500 individuals per m^2) following maximum spawning activity between May and July (Farke, 1979). However, the spawning period varies according to environmental conditions and so peak abundances will not necessarily occur at the same time each year. Adult densities of the bivalve, *Abra alba*, may exceed 1000 per m^2 in favourable conditions but typically fluctuate widely from year to year due to variation in recruitment success or adult mortality (see review by Rees & Dare, 1993).
Macroalgal cover typically varies through the year due to temperature and light availability. *Fucus serratus* plants, for example, lose fronds in the winter, followed by regrowth from existing plants in late spring and summer, so that summer cover can be about 250% of the winter level (Hartnoll & Hawkins, 1980). Production by microphytobenthos and microalgae is also likely to be higher in spring and summer, increasing food availability for grazers, deposit feeders and suspension feeders.
One of the key factors affecting benthic habitats is disturbance, which in shallow subtidal habitats increases in winter due to weather conditions. Storms may cause dramatic changes in distribution of macro-infauna by washing out dominant species, opening the sediment to recolonization by adults and/or available spat/larvae (Eagle, 1975; Rees *et al*., 1977; Hall, 1994) and by reducing success of recruitment by newly settled spat or larvae (see Hall 1994 for review). For example, during winter gales along the North Wales coast, large numbers of *Abra alba* were cast ashore and over winter survival rate was as low as 7% in the more exposed locations. The survival rates of the bivalve, *Kurtiella bidentata*, and the polychaete, *Notomastus latericeus*, were 50% and 12% respectively (Rees *et al*., 1977). Sediment transport and the risk of smothering also occurs. A storm event at a silt/sand substratum site in Long Island Sound resulted in the deposition of a 1cm layer of shell fragments and quartz grains (McCall, 1977).

Habitat structure and complexity

- The mixed sediment in this biotope is the important structural component, providing the complexity required by the associated community. Epifauna and algae are attached to the gravel and pebbles and infauna burrow in the soft underlying sediment. Sediment deposition, and therefore the spatial extent of the biotope, is dictated by the physiography and underlying geology coupled with the hydrodynamic regime (Elliot *et al*., 1998).
- There is a traditional view that the distribution of infaunal invertebrates is correlated solely with sediment grain size. In reality, and in this biotope, it is likely that a number of additional factors, including organic content, microbial content, food supply and trophic interactions, interact to determine the distribution of the infauna (Snelgrove & Butman, 1994).
- Reworking of sediments by deposit feeders, such as *Arenicola marina*, increases bioturbation and potentially causes a change in the substratum characteristics and the associated community (e.g. Rhoads & Young, 1970). The presence of tube builders, such as *Lanice conchilega*, stabilizes the sediment and provides additional structural complexity.
- The presence of macroalgae, such as *Fucus serratus* and *Osmundea pinnatifida*, increases structural complexity in the biotope, providing shelter and cover for mobile fauna. The fronds increase the area available for attachment of epifauna and epiphytes.

Productivity

Primary production in this biotope comes predominantly from benthic microalgae (microphytobenthos e.g. diatoms, flagellates and euglenoides) and water column phytoplankton. Macroalgae, although not very abundant in the biotope also contribute to primary production. They exude considerable amounts of dissolved organic carbon which are taken up readily by bacteria and possibly by some larger invertebrates. Only about 10% of the primary production on rocky shores is directly cropped by herbivores (Raffaelli & Hawkins, 1999) and the figure is likely to be similar or less in this biotope. Photosynthetic processes may be light limited due to the turbidity of the water (Elliot *et al.*, 1998) and *in situ* primary production overall is likely to be low. Large allochthonous inputs of nutrients, sediment and organic matter come from river water and the sea, containing both naturally derived nutrients and anthropogenic nutrients (e.g. sewage) (Elliot *et al.*, 1998). The allochthonous nutrient input results in enriched sediments and explains the high biomass of detritivores and deposit feeders.

Recruitment processes

Characteristic and other species in the biotope recruit as larvae and spores from the plankton. More detailed information is given for dominant and characteristic species below.

- *Venerupis senegalensis* is a long lived, fast growing species that reaches maturity within one year and spawns several times in one season (Johannessen, 1973b; Perez Camacho, 1980). No information was found concerning number of gametes produced, but the number is likely to be high as with other bivalves exhibiting planktotrophic development (Olafsson *et al.*, 1994). The larvae remain in the plankton for up to 30 days (Fish & Fish, 1996) and hence have a high potential for dispersal. The species exhibits pronounced year class variability in abundance (Johannessen, 1973; Perez Camacho, 1980) which suggests that recruitment is patchy and/or post settlement processes are highly variable. Olafsson *et al.* (1994) reviewed the potential effects of pre and post recruitment processes. Recruitment may be limited by predation of the larval stage or inhibition of settlement due to intraspecific density dependent competition. Post settlement processes affecting survivability include predation by epibenthic consumers, physical disturbance of the substratum and density dependent starvation of recent recruits. Hence, for *Venerupis senegalensis*, annual predictable recruitment is unlikely to occur.
- Recruitment of shallow burrowing infaunal species can depend on adult movement by bedload sediment transport and not just spat settlement. Emerson & Grant (1991) investigated recruitment in *Mya arenaria* and found that bedload transport was positively correlated with clam transport. They concluded that clam transport at a high energy site accounted for large changes in clam density. Furthermore, clam transport was not restricted to storm events and the significance is not restricted to *Mya arenaria* recruitment. Many infauna, e.g. polychaetes, gastropods, nematodes and other bivalves, will be susceptible to movement of their substratum.
- The infaunal polychaetes *Arenicola marina* and *Aphelochaeta marioni* have high fecundity and the eggs develop lecithotrophically within the sediment or at the sediment surface (Farke, 1979; Beukema & de Vlas, 1979). There is no pelagic larval phase and the juveniles disperse by burrowing. Recruitment must occur from local populations or by longer distance dispersal during periods of bedload transport. Recruitment is therefore likely to be predictable if local populations exist but patchy and sporadic otherwise.
- The epifaunal gastropods in the biotope, such as *Littorina littorea*, are iteroparous, highly fecund and disperse via a lengthy pelagic larval phase. Recruitment is probably sporadic

and opportunistic, large spat fall occurring when a suitable substratum and food supply becomes available.
- Recruitment of *Fucus serratus* from minute pelagic sporelings takes place from late spring until October. There is a reproductive peak in the period August - October and dispersal may occur over long distances (up to 10 km). However, weak tidal streams may result in a smaller supply of pelagic sporelings and most recruitment probably comes from local populations.

Time for community to reach maturity

Venerupis senegalensis is the important characterizing species in the biotope. It is highly fecund and fast growing (Johannessen, 1973b; Perez Camacho, 1980; Olafsson *et al.*, 1994) and therefore is likely to attain high numbers in the community rapidly. The same is true for the majority of other infauna, epifauna and flora in the biotope. It is predicted therefore that the community will reach maturity in less than 5 years.

Additional information

no text entered.

Preferences & Distribution

Habitat preferences

Depth Range	0-5 m, 5-10 m, 10-20 m, 20-30 m
Water clarity preferences	Field Unresearched
Limiting Nutrients	Nitrogen (nitrates), Phosphorus (phosphates)
Salinity preferences	Full (30-40 psu), Variable (18-40 psu)
Physiographic preferences	
Biological zone preferences	Infralittoral
Substratum/habitat preferences	Muddy sandy gravel
Tidal strength preferences	Moderately Strong 1 to 3 knots (0.5-1.5 m/sec.), Weak < 1 knot (<0.5 m/sec.)
Wave exposure preferences	Extremely sheltered, Sheltered, Very sheltered
Other preferences	

Additional Information

Species composition

Species found especially in this biotope

- *Venerupis senegalensis*

Rare or scarce species associated with this biotope

-

Additional information

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The biotope description and characterizing species are taken from (JNCC, 2015).Sheltered muddy sandy gravel and pebbles in marine inlets, estuaries or embayments with variable salinity or fully marine conditions, support large populations of the pullet carpet shell *Venerupis senegalensis* (accepted name now *Venerupis corrugata*) with the brittlestar *Amphipholis squamata* and the tanaid *Apseudes latreilli*. These species are considered to characterize the biotope and the sensitivity assessments focus on these species. The assessments consider generally the sensitivity of associated polychaetes such as *Mediomastus fragilis*, *Melinna palmata*, *Aphelochaeta marioni*, and tubificid oligochaetes.

Resilience and recovery rates of habitat

The recoverability of the important characterizing species in this biotope, *Venerupis senegalensis*, is the principal factor in assessing the recoverability of the biotope. *Venerupis senegalensis* is a long lived, fast growing species that reaches maturity within one year and spawns several times in one season (Johannessen, 1973b; Perez Camacho, 1980). No information was found concerning number of gametes produced, but the number is likely to be high as with other bivalves exhibiting planktotrophic development (Olafsson *et al.*, 1994). The larvae remain in the plankton for up to 30 days (Fish & Fish, 1996) and hence have a high potential for dispersal. Given these life history features, it is expected that *Venerupis senegalensis* would have strong powers of recoverability. However, recoverability will be influenced by pre and post recruitment processes. The species exhibits pronounced year class variability in abundance (Johannessen, 1973b; Perez Camacho, 1980) which suggests that recruitment is patchy and/or post settlement processes are highly variable. Olafsson *et al.* (1994) reviewed the potential effects of pre and post recruitment processes. Recruitment may be limited by predation of the larval stage or inhibition of settlement due to intraspecific density dependent competition. Post settlement processes affecting survivability include predation by epibenthic consumers, physical disturbance of the substratum and density dependent starvation of recent recruits. Hence, for *Venerupis senegalensis*, an annual predictable population recovery is not certain. However, given the life history characteristics discussed above it is expected that recovery would occur within 5 years and therefore recoverability for *Venerupis senegalensis* is assessed as high.

Species with opportunistic life strategies (small size, rapid maturation and short-lifespan of 1-2 years with production of large numbers of small propagules), include the characterizing polychaetes *Mediomastus fragilis* and *Amphipholis squamata*. Tubificid populations tend to be large and to be constant throughout the year, although some studies have noticed seasonal variations (Giere & Pfannkuche, 1982). Many species, including *Tubificoides benedii* have a two-year reproductive cycle and only part of the population reproduces each season (Giere & Pfannkuche, 1982). Tubificids have a long lifespan (a few years, Giere, 2006), a prolonged reproductive period from reaching maturity to maximum cocoon deposition and internal fertilisation with brooding rather than pelagic dispersal. These factors mean that recolonization is slower than for some opportunistic species which may be present in similar habitats.

Bolam and Whomersley (2003) observed faunal recolonization of fine sediments placed on saltmarsh as a beneficial use and disposal of fine-grained dredged sediments. They found that tubificid oligochaetes began colonising sediments from the first week following a beneficial use scheme involving the placement of fine-grained dredged material on a salt marsh in southeast

England. The abundance of *Tubificoides benedii* recovered slowly in the recharge stations and required 18 months to match reference sites and those in the recharge stations prior to placement of sediments. The results indicate that some post-juvenile immigration is possible and that an in-situ recovery of abundance is likely to require more than 1 year.

Resilience assessment. The majority of species in the biotope are likely to have high recoverability. In light of this, and particularly the recoverability of the important characterizing species, *Venerupis senegalensis*, recoverability of the biotope as a whole is assessed as 'high', to all levels of impact.

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

Hydrological Pressures

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

The geographic range of the key characterizing species *Venerupis corrugata* extends to northern Africa. Therefore, the species must be capable of surviving in higher temperatures than it experiences in Britain and Ireland and thus would be expected to tolerate temperature change over an extended period. A population of *Venerupis corrugata* endured a temperature rise from 13 to 18°C over 5 hours in a rockpool and then a drop to 14°C following inundation by the tide, with no obvious ill effects (Stenton-Dozey & Brown, 1994). Albentosa *et al.* (1994) found that scope for growth of *Venerupis corrugata* increases to an optimum at 20°C and then declines.

Sensitivity assessment. It is expected that *Venerupis corrugata* and other characterizing species would be able to tolerate a long-term, chronic temperature increase and a short-term acute change with no mortality. However, a rapid increase in temperature may result in sub-optimal conditions for growth and reproduction. Resistance of the biotope is assessed as 'High' and resilience as 'High' (by default), so the biotope is considered to be 'Not sensitive' at the pressure benchmark.

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

The geographic range of *Venerupis corrugata* extends to northern Norway. Therefore, the species must be capable of survival at lower temperatures than it does in Britain and Ireland and would be expected to tolerate a chronic temperature decrease over an extended period. However, in the harsh British winter of 1962-63, when the south coast experienced temperatures 5-6°C below average for a period of 2 months, *Venerupis corrugata* (studied as *Venerupis pullastra*) suffered 50% mortality around the Isle of Wight and near 100% mortality in Poole Harbour (Waugh, 1964).

Other species within the biotope are likely to be more tolerant. Most oligochaetes, including tubificids and enchytraeids, can survive freezing temperatures and can survive in frozen sediments (Giere & Pfannkuche, 1982). *Tubificoides benedii* (studied as *Peloscolex benedeni*) recovered after being frozen for several tides in a mudflat (Linke, 1939).

Sensitivity assessment. A chronic decrease in temperature at the pressure benchmark is likely to be tolerated. However, an acute decrease in temperature may result in mortalities during the coldest part of the year. Biotope resistance is assessed as 'Low' and resilience as 'High', so that sensitivity is assessed as 'Low'.

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

This biotope is recorded from habitats where salinity is variable (18-35 ppt) or full (30-35 ppt) (JNCC, 2015). Biotopes in variable salinity are likely to be tolerant of an increase in salinity to full as this falls within the natural habitat range. An increase in salinity to hypersaline conditions (>40 ppt) is assessed. No direct evidence was found to assess this pressure for the characterizing species. The ophiuroid *Amphipholis squamata* has been recorded in areas of high salinity (52-55 ppt) in the Arabian Gulf (Price, 1982), indicating local acclimation may be possible. A study from the Canary Islands indicates that exposure to high salinity effluents (47- 50 psu) from desalination plants alter the structure of biological assemblages, reducing species richness and abundance (Riera *et al*., 2012). Bivalves appear to be less tolerant of increased salinity than polychaetes and were largely absent at the point of discharge.

Sensitivity assessment. High saline effluents alter the structure of biological assemblages. Polychaete species may be more tolerant than bivalves but an increase in salinity is likely to result in declines in species richness and abundance based on Riera *et al*. (2012). Biotope resistance is assessed as 'Low' and resilience as 'High', (following a return to typical conditions). Biotope sensitivity is assessed as 'Low'.

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

The biotope occurs in full (30-35 ppt) and variable(18-35 ppt) salinity conditions (JNCC< 2015), biotopes occurring in full salinity are likely to be tolerant of a reduction to variable, as this falls within the natural range. No information was found concerning the effects of decreasing salinity on the species specifically. However, Lange (1972) reported that the muscle volume of *Venerupis rhomboides*, a stenohaline species, increased as salinity decreased, and hence concluded that the species was unable to regulate its muscle volume. *Venerupis japonica* displayed a variety of behavioural reactions in response to reduced salinity in the Sea of Japan (Yaroslavtseva & Fedoseeva, 1978). Salinities typically encountered ranged from 11-30 psu over the course of a day. *Venerupis japonica* was active down to 20 psu, below which it reacted with siphon withdrawal and valve closure. Mortality occurred if salinity remained below 14 psu for an extended period.

Sensitivity assessment. A reduction in salinity may result in changes in biotope composition as some sensitive species are lost and replaced species more tolerant of the changed conditions.

Biotope resistance is therefore assessed as 'Low' and resilience as 'High'. Biotope sensitivity is assessed as 'Medium'.

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

No direct evidence was found to assess this pressure. This biotope is recorded in areas where tidal flow varies between moderately strong (0.5-1.5 m/s) and weak (>0.5 m/s) (JNCC, 2015).

Sensitivity assessment. A change at the pressure benchmark (increase or decrease) is unlikely to affect biotopes that occur in mid-range flows and biotope resistance is therefore assessed as 'High' and resilience is assessed as 'High', so the biotope is considered to be 'Not sensitive'.

Emergence regime changes	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant to sublittoral biotopes.

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

As this biotope occurs in infralittoral habitats, it is not directly exposed to the action of breaking waves. Associated polychaete and oligochaete species that burrow are protected within the sediment but the characterizing bivalves would be exposed to oscillatory water flows at the seabed. They and other associated species may be indirectly affected by changes in water movement where these impact the supply of food or larvae or other processes. No specific evidence was found to assess this pressure. As the biotope occurs in habitats that are sheltered from wave action (JNCC, 2015), with habitat exposure ranging from sheltered, very sheltered to extremely sheltered (JNCC, 2015), it is considered that a change in wave height at the pressure benchmark would be small and would fall within the natural range.

Sensitivity assessment. The range of wave exposures experienced by the biotope is considered to indicate, by proxy, that the biotope would have 'High' resistance and by default 'High' resilience to a change in significant wave height at the pressure benchmark. The biotope is therefore classed as 'Not sensitive'.

Chemical Pressures

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

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

The capacity of bivalves to accumulate heavy metals in their tissues, far in excess of environmental levels, is well known. Reactions to sub-lethal levels of heavy metal stressors include siphon retraction, valve closure, inhibition of byssal thread production, disruption of burrowing behaviour, inhibition of respiration, inhibition of filtration rate, inhibition of protein synthesis and suppressed growth (see review by Aberkali & Trueman, 1985). No evidence was found directly relating to *Fabulina fabula*. However, inferences may be drawn from studies of a closely related species. Stirling (1975) investigated the effect of exposure to copper on *Tellina tenuis*. The 96 hour LC_{50} for Cu was 1000 µg/l. Exposure to Cu concentrations of 250 µg/l and above inhibited burrowing behaviour and would presumably result in greater vulnerability to predators. Similarly, burial of *Venerupis corrugata*, was inhibited by copper spiked sediments, and at very high concentrations, clams closed up and did not bury at all (Kaschl & Carballeira, 1999). The copper 10 day LC_{50} for *Venerupis corrugata* (as *Venerupis senegalensis*) was found to be 88 µg/l in sandy sediments (Kaschl & Carballeira, 1999).

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

It should be noted that experimental exposures to heavy metals in the laboratory are likely to be far higher than those encountered in the sea and therefore the real effect *in vivo* may be far less.

Hydrocarbon & PAH contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

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

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

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

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

Stamouli & Papadapoulou (1990) investigated bioaccumulation of radioactive trivalent Chromium 51 (^{51}Cr) in a *Venerupis* species from Greece. ^{51}Cr is derived from nuclear tests, disposal of radioactive waste and is one of the principal corrosion products of nuclear powered ships. ^{51}Cr was found to rapidly accumulate in *Venerupis* sp., predominantly in the shell, and reached a stable level in 8 days. No mortality was reported after 20 days. No further information was found concerning the uptake of radionuclides by species in the biotope.

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

This pressure is **Not assessed**.

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

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

Tubificoides live relatively deeply buried and can tolerate periods of low oxygen that may occur following the deposition of a fine layer of sediment. In addition, the presence of this species in areas experiencing deposition, such as estuaries, indicate that this species is likely to have a high tolerance to siltation events. *Tubificoides* spp. showed some recovery through vertical migration following the placement of a sediment overburden 6cm thick on top of sediments (Bolam, 2011).

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

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 pressure benchmark is set at compliance with Water Framework Directive (WFD) criteria for good status, based on nitrogen concentration (UKTAG, 2014).

Nutrient enrichment can lead to significant shifts in community composition in sedimentary habitats. Typically the community moves towards one dominated by deposit feeders and detritivores, such as polychaete worms (see review by Pearson & Rosenberg, 1978). The biotope includes species tolerant of nutrient enrichment and typical of enriched habitats (e.g. *Tubificoides benedii*) (Pearson & Rosenberg, 1978). It is likely that such species would increase in abundance following nutrient enrichment, with an associated decline in suspension feeding species such as bivalves.

No information regarding the specific effects of nutrients on *Venerupis corrugata*, the important characterizing species, was found. However, increased nutrients are likely to enhance ephemeral algal and phytoplankton growth, increase organic material deposition and enhance bacterial growth. At low levels, an increase in phytoplankton and benthic diatoms may increase food availability for *Venerupis corrugata*, thus enhancing growth and reproductive potential (e.g. Beiras *et al*., 1993). However, increased levels of nutrient (beyond the carrying capacity of the environment) may result in eutrophication, algal blooms and reductions in oxygen concentrations (e.g. Rosenberg & Loo, 1988).

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

	Resistance	Resilience	Sensitivity
Organic enrichment	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

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

Physical Pressures

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

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

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

The biotope is characterized by the sedimentary habitat (JNCC, 2015), a change to an artificial or rock substratum would alter the character of the biotope leading to reclassification and the loss of the sedimentary community including the characterizing bivalve *Venerupis corrugata* and the associated polychaetes that live buried within the sediment.

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

Physical change (to another sediment type)	Low Q: Low A: NR C: NR	Very Low Q: High A: High C: High	High Q: Low A: Low C: Low

The change referred to at the pressure benchmark is a change in sediment classification (based on Long, 2006) rather than a change in the finer-scale original Folk categories (Folk, 1954). For mixed sediments, resistance is assessed based on a change to either coarse sediments or mud and sandy muds.

Sensitivity assessment. Changes in the sediment type may lead to biotope reclassification. Biotope resistance is, therefore, assessed as 'Low' (as some species may remain), as resilience is Very low (the pressure is a permanent change), sensitivity is, therefore, High.

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

Sedimentary communities are likely to be highly intolerant of substratum removal, which will lead to partial or complete defaunation, exposing underlying sediment which may be anoxic and/or of a different character or bedrock and lead to changes in the topography of the area (Dernie *et al.*, 2003). Any remaining species, given their new position at the sediment/water interface, may be exposed to conditions to which they are not suited. Removal of 30 cm of surface sediment will remove the polychaete and oligochaete community and other species present in the biotope. Recovery of the biological assemblage may take place before the original topography is restored, if the exposed, underlying sediments are similar to those that were removed. Hydrodynamics and sedimentology (mobility and supply) influence the recovery of soft-sediment habitats (Van Hoey *et al.*, 2008).

Sensitivity assessment. Extraction of 30 cm of sediment will remove the characterizing biological component of the biotope. Resistance is assessed as 'None' and biotope resilience is assessed as 'Medium'. Biotope sensitivity is therefore 'Medium'.

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

Abrasion may damage or kill a proportion of the population of the characterizing species. Biotope resistance is assessed as 'Medium' and resilience as 'High', so sensitivity is assessed as 'Low'.

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

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

Sensitivity assessment. Biotope resistance is assessed as 'Medium' as some species will be displaced and may be predated or injured and killed. Biotope resilience is assessed as 'High' as most species will recover rapidly and the biotope is likely to still be classified as SS.SMx.IMx.VsenAsquAps following disturbance. Biotope sensitivity is therefore assessed as 'Low'.

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

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

Venerupis corrugata is an active suspension feeder, trapping food particles on the gill filaments (ctenidia). An increase in suspended sediment is, therefore, likely to affect both feeding and respiration by potentially clogging the ctenidia. In *Venerupis corrugata*, increased particle concentrations between low and high tide resulted in increased clearance rates and pseudofaeces production with no significant increase in respiration rate (Stenton-Dozey & Brown, 1994).

Changes in turbidity and seston are not predicted to directly affect deposit feeding polychaetes and oligochaetes which live within sediments. The majority of species in the biotope are either suspension feeders or deposit feeders and therefore rely on a supply of nutrients in the water column and at the sediment surface. A decrease in suspended organic material would result in decreased food availability for suspension feeders. It would also result in a decreased rate of deposition on the substratum surface and therefore a reduction in food availability for deposit feeders. This would be likely to impair growth and reproduction.

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

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

The addition of fine material will alter the character of this habitat by covering it with a layer of dissimilar sediment and will reduce suitability for the species associated with this feature. Recovery will depend on the rate of sediment mixing or removal of the overburden, either naturally or through human activities. Recovery to a recognisable form of the original biotope will not take place until this has happened. In areas where the local hydrodynamic conditions are unaffected, fine particles will be removed by wave action moderating the impact of this pressure. The rate of habitat restoration would be site-specific and would be influenced by the type of siltation and rate. Long-term or permanent addition of fine particles would lead to re-classification of this biotope type (see physical change pressures).

Suspension feeding bivalves may be sensitive to deposition. The additions of silts to a *Spisula solida* bed in Waterford Harbour (Republic of Ireland) from earthworks further upstream, for example, reduced the extent of the bed (Fahy *et al*., 2003). No information was provided on the depth of any deposits.

Venerupis corrugata typically burrows to a depth of 3-5 cm and is often attached to small stones or shell fragments by byssal threads. It is an active suspension feeder and therefore requires its siphons to be above the sediment surface in order to maintain a feeding and respiration current. Kranz (1972, cited in Maurer *et al.*, 1986) reported that shallow burying siphonate suspension feeders are typically able to escape smothering with 10-50 cm of their native sediment and relocate to their preferred depth by burrowing. This is likely to apply to the proportion of the *Venerupis corrugata* population which is not firmly attached by byssal threads. However, those individuals which are attached may be inhibited from relocating rapidly following smothering with 5 cm of sediment and some mortality is expected to occur.

Sensitivity assessment. This biotope is exposed to tidal streams which may remove some sediments and the bivalves and polychaetes are likely to be able to survive short periods under sediments and to reposition. Based on *Venerupis corrugata*, biotope resistance is assessed as ‘Low’ and resilience as ‘High’. So that biotope sensitivity is assessed as ‘Low’.

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

No direct evidence was found to assess this pressure for *Venerupis senegalensis* and other characterizing species. Powilleit *et al.* (2009) studied responses to smothering for three bivalves; *Arctica islandica*, *Limecola balthica* and *Mya arenaria*. These successfully burrowed to the surface of a 32 –41cm deposited sediment layer of till or sand/till mixture and restored contact with the overlying water. These high escape potentials could partly be explained by the heterogeneous texture of the till and sand/till mixture with ‘voids’. In comparison to a thick coverage, thin covering layers (i.e. 15 -16 cm and 20 cm) increased the chance of the organisms to reach the sediment surface after burial. While crawling upward to the new sediment surfaces burrowing velocities of up to 8 cm/day were observed for the bivalves.

Sensitivity assessment. The pressure benchmark (30 cm deposit) represents a significant burial event and the deposit may remain for some time in wave sheltered areas. Some impacts on characterizing are likely to occur as it is considered unlikely that significant numbers of the population could reposition. Placement of the deposit will, therefore, result in a defaunated habitat until the deposit is recolonized. Biotope resistance is assessed as 'Low' as some removal of deposit and vertical migration through the deposit may occur. Resilience is assessed as 'High' as migration and recolonization of characterizing species is likely to occur within two years, biotope sensitivity is therefore assessed as 'Low'.

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

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.

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

Not relevant.

Introduction of light or shading	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

All characterizing species live in the sediment and do not rely on light levels directly to feed so limited direct impact is expected. As this biotope is not characterized by the presence of primary producers it is not considered that shading would alter the character of the habitat directly.

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

The key characterizing bivalve species produce pelagic larvae as do many of the polychaete species. Barriers that reduce the degree of tidal excursion may alter larval supply to suitable habitats from source populations. Conversely, the presence of barriers may enhance local population supply by preventing the loss of larvae from enclosed habitats. As the bivalve species characterizing the biotope are widely distributed and produce large numbers of larvae capable of long distance transport and survival, resistance to this pressure is assessed as 'High' and resilience as 'High' by default. This biotope is therefore considered to be 'Not sensitive'. Some species such as the oligochaetes that occur within the biotope have benthic dispersal strategies (via egg masses laid on the surface) and water transport is not a key method of dispersal over wide distances

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 majority of the species in the biotope, including *Venerupis senegalensis*, have very little or no visual acuity, and are therefore unlikely to be intolerant of visual disturbance. Some species, however, respond to visual disturbance by withdrawal of feeding structures and are therefore likely to experience some energetic cost through loss of feeding opportunities. *Aphelochaeta marioni*, for example, feeds only at night, and responds to sudden light pollution by the retraction of palps and cirri and cessation of all activity for some minutes (Farke, 1979). This pressure is therefore considered '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 are not translocated or cultivated and this pressure is considered to be 'Not relevant'. In Europe, *Venerupis corrugata* is reared in hatcheries with subsequent relocation to natural habitats to grow, this assessment will require updating if such practices became established in the UK.

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

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

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

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

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

Bacterial diseases are frequently found in molluscs during their larval stages, but seem to be relatively insignificant in populations of adult animals (L�pez et al., 2004). This may be due to the primary defence mechanisms of molluscs, phagocytosis and encapsulation, which fight against small-sized pathogens, and whose resistance may be age related (Sindermann, 1990, from L�pez-Flores *et al*., 2004). Pathogens that have been recorded to affect *Venerupis* spp. include 'Hinge ligament disease', caused by a *Cytophaga*-like bacteria, was detected in *Venerupis philippinarum* (*Ruditapes philippinarum*) in the US. The disease has little or no effect on healthy growing juveniles (Bower *et al*., 1994a). Virus-like particles similar to picornaviruses and parvoviruses have been associated with brown muscle disease in *Venerupis philippinarum* (*Ruditapes philippinarum*) populations with mortalities, in France (Dang & De Montaudouin, 2009). *Perkinsus* spp. have been associated with mass mortalities of *Venerupis decussata* from the south coast of Portugal, and with epizootic mortalities of *Venerupis philippinarum* in Korea, China and Japan (Villalba *et al*., 2004; Choi & Park, 2005). Navas *et al.* (1992) investigated the parasites of *Venerupis senegalensis* (studied as *Venerupis pullastra*), from a population in south west Spain. The following were recorded:

- 36.6% prevalence of *Perkinsus atlanticus*; trophozoites found in the connective tissue of different organs with a very intensive hemocytic response, encysting the parasite and destroying tissue structure.
- 96.6% prevalence of ciliates in gills, including *Trichodina* sp.
- 11.8% prevalence of turbellarians.
- 11.1% prevalence of trematodes.

Perkinsus atlanticus was also recorded as causing mortality in *Venerupis decussata* and *Venerupis aureus*. Freire-Santos *et al.* (2000) recorded the presence of oocysts of *Cryptosporidium* sp. in *Venerupis corrugata* (studied as *Venerupis pullastra*) collected from north west Spain and destined for human consumption.

Little information on pathogens is available for other species that characterize this biotope, although Gibbs (1971) recorded that nearly all of the population of *Aphelochaeta marioni* in Stonehouse Pool, Plymouth Sound, was infected with a sporozoan parasite belonging to the acephaline gregarine genus *Gonospora*, which inhabits the coelom of the host. No evidence was found to suggest that gametogenesis was affected by *Gonospora* infection and there was no apparent reduction in fecundity.

Sensitivity assessment. The parasite loads of the bivalves discussed above have been proven to cause mortality and therefore biotope resistance is assessed as 'Medium' as there may be a minor decline in species richness in the biotope and a reduction in abundance of the key characterizing species *Venerupis corrugata*. Resilience is assessed as 'High' and biotope sensitivity is assessed as 'Low'.

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

Venerupis corrugata is a very important commercial shellfish in Spain. It is harvested from the wild and raised in aquaculture (Jara-Jara *et al*., 2000).

Sensitivity assessment. Biotope resistance to targeted removal is assessed as 'Low' and resilience as 'High', as the habitat is likely to be directly affected by removal but the targeted species are likely to recolonize rapidly. Some variability in species recruitment, abundance and composition is natural and therefore a return to a recognizable biotope should occur within 2 years. Repeated chronic removal would, however, impact recovery.

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

Species within the biotope are not functionally dependent on each other, although biological interactions will play a role in structuring the biological assemblage through predation and competition. Removal of adults may support recruitment of juvenile bivalves by reducing competition for space and consumption of larvae.

Removal of species would also reduce the ecological services provided by these species such as secondary production and nutrient cycling.

Sensitivity assessment. Species within the biotope are relatively sedentary or slow moving, although the infaunal position may protect some burrowing species from removal. Biotope resistance is therefore assessed as ‘Low’ and resilience as ‘High’, as the habitat is likely to be directly affected by removal but some species will recolonize rapidly. Biotope sensitivity is assessed as 'Low'.

Bibliography

Aberkali, H.B. & Trueman, E.R., 1985. Effects of environmental stress on marine bivalve molluscs. *Advances in Marine Biology*, **22**, 101-198.

Albentosa, M., Beiras, R. & Camacho, A.P., 1994. Determination of optimal thermal conditions for growth of clam (*Venerupis pullastra*) seed. *Aquaculture*, **126**, 315-328.

Ansell, A.D., Barnett, P.R.O., Bodoy, A. & Masse, H., 1981. Upper temperature tolerances of some European Mollusca III. *Cardium glaucum*, *C. tuberculata* and *C. edule*. *Marine Biology*, **65**, 177-183.

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

Beiras, R., Perez-Camacho, A. & Albentosa, M., 1993. Influence of food concentration on energy balance and growth performance of *Venerupis pullastra* seed reared in an open flow system. *Aquaculture*, **116**, 353-365.

Beukema, J.J. & De Vlas, J., 1979. Population parameters of the lugworm, *Arenicola marina*, living on tidal flats in the Dutch Wadden Sea. *Netherlands Journal of Sea Research*, **13**, 331-353.

Beukema, J.J., 1995. Long-term effects of mechanical harvesting of lugworms *Arenicola marina* on the zoobenthic community of a tidal flat in the Wadden Sea. *Netherlands Journal of Sea Research*, **33**, 219-227.

Blanchard, M., 1997. Spread of the slipper limpet *Crepidula fornicata* (L.1758) in Europe. Current state and consequences. *Scientia Marina*, **61**, Supplement 9, 109-118.

Bohn, K., Richardson, C.A. & Jenkins, S.R., 2015. The distribution of the invasive non-native gastropod *Crepidula fornicata* in the Milford Haven Waterway, its northernmost population along the west coast of Britain. *Helgoland Marine Research*, **69** (4), 313.

Bolam, S. & Whomersley, P., 2003. Invertebrate recolonization of fine-grained beneficial use schemes: An example from the southeast coast of England. *Journal of Coastal Conservation*, **9** (2), 159-169.

Bolam, S.G., 2011. Burial survival of benthic macrofauna following deposition of simulated dredged material. *Environmental Monitoring and Assessment*, **181** (1-4), 13-27.

Bower, S.M., McGladdery, S.E. & Price, I.M., 1994. Synopsis of infectious diseases and parasites of commercially exploited shellfish. *Annual Review of Fish Diseases*, **4**, 1-199.

Bradshaw, C., Veale, L.O., Hill, A.S. & Brand, A.R., 2000. The effects of scallop dredging on gravelly seabed communities. In: *Effects of fishing on non-target species and habitats* (ed. M.J. Kaiser & de S.J. Groot), pp. 83-104. Oxford: Blackwell Science.

Brouseau, D.J. & Baglivo, J.A., 1991. Disease progression and mortality in neoplastic *Mya arenaria* in the field. *Marine Biology*, **110**, 249-252.

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

Bryan, G.W. & Langston, W.J., 1992. Bioavailability, accumulation and effects of heavy metals in sediments with special reference to UK estuaries: a review. *Environmental Pollution*, **76**, 89-131.

Bryan, G.W., 1984. Pollution due to heavy metals and their compounds. In *Marine Ecology: A Comprehensive, Integrated Treatise on Life in the Oceans and Coastal Waters*, vol. 5. *Ocean Management*, part 3, (ed. O. Kinne), pp.1289-1431. New York: John Wiley & Sons.

Chassaud-Bouchard, C., 1992. Biological effects of uranium and transuranium nuclides on marine bivalves *Mytilus edulis*, *Crassostrea gigas* and *Cerastoderma edule*: microanalysis at the cellular and subcellular levels. In *Proceedings of the FAO/UNEP/IOC Workshop on the biological effects of pollutants on marine organisms, 10-14 September 1991, Malta.* (ed. G.D. Gabrielides).(*MAP Technical Report Series*, no. 69.), Athens: UNEP.

Choi, H.G. & Norton, T.A., 2005. Competition and facilitation between germlings of *Ascophyllum nodosum* and *Fucus vesiculosus*. *Marine Biology*, **147**(2), 525-532.

Clarke, M. R., 1966. A review of the systematics and ecology of oceanic squids. *Advanced Marine Biology*, **4**, 91-300.

Clay, E., 1966. Literature survey of the common fauna of estuaries. 12. *Mya arenaria* L., *Mya truncata* L. *Imperial Chemical Industries Limited, Brixham Laboratory*, BL/A/707.

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

Connor, D.W., 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.

Cotter, A.J.R., Walker, P., Coates, P., Cook, W. & Dare, P.J., 1997. Trial of a tractor dredger for cockles in Burry Inlet, South Wales. *ICES Journal of Marine Science*, **54**, 72-83.

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

Cryer, M., Whittle, B.N. & Williams, K., 1987. The impact of bait collection by anglers on marine intertidal invertebrates. *Biological Conservation*, **42**, 83-93.

Dang, C. & De Montaudouin, X., 2009. Brown muscle disease and Manila clam *Ruditapes philippinarum* dynamics in Arcachon Bay, France. *Journal of Shellfish Research*, **28** (2), 355-362.

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

De Montaudouin, X. & Sauriau, P.G., 1999. The proliferating Gastropoda *Crepidula fornicata* may stimulate macrozoobenthic diversity. *Journal of the Marine Biological Association of the United Kingdom*, **79**, 1069-1077.

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

Dow, R.C., 1978. Size-selective mortalities of clams in an oil spill site. *Marine Pollution Bulletin*, **9**, 45-48.

Dow, R.L. & Wallace, D.E., 1961. The soft-shell clam industry of Maine. *U.S. Fish and Wildlife Service, Department of the Interior, Circular* no. 110., U.S.A: Washington D.C.

Eagle, R.A., 1975. Natural fluctuations in a soft bottom benthic community. *Journal of the Marine Biological Association of the United Kingdom*, **55**, 865-878.

Eisler, R., 1977. Toxicity evaluation of a complex meta mixture to the softshell clam *Mya arenaria*. *Marine Biology*, **43**, 265-276.

Emerson, C.M., Grant, J. & Rowell, T.W., 1990. Indirect effects of clam digging on the viability of soft-shell clams, *Mya arenaria* L. *Netherlands Journal of Sea Research*, **27**, 109-118.

Emerson, C.W. & Grant, J., 1991. The control of soft-shell clam (*Mya arenaria*) recruitment on intertidal sandflats by bedload sediment transport. *Limnology and Oceanography*, **36**, 1288-1300.

Eno, N.C., Clark, R.A. & Sanderson, W.G. (ed.) 1997. *Non-native marine species in British waters: a review and directory.* Peterborough: Joint Nature Conservation Committee.

Fahy, E., Carroll, J. & O'Toole, M., 2003. A preliminary account of fisheries for the surf clam *Spisula solida* (L) (Mactracea) in Ireland [On-line] http://www.marine.ie, 2004-03-16

Farke, H., 1979. Population dynamics, reproduction and early development of *Tharyx marioni* (Polychaeta, Cirratulidae) on tidal flats of the German Bight. *Veroffentlichungen des Instituts fur Meeresforschung in Bremerhaven*, **18**, 69-99.

Feder, H.M. & Pearson, T.H., 1988. The benthic ecology of Loch Linnhe and Loch Eil, a sea-loch system on the west coast of Scotland. 5. Biology of the dominant soft-bottom epifauna and their interaction with the infauna. *Journal of Experimental Marine Biology and Ecology*, **116**, 99-134.

Fish, J.D. & Fish, S., 1996. *A student's guide to the seashore.* Cambridge: Cambridge University Press.

Flach, E.C., 1992. Disturbance of benthic infauna by sediment-reworking activities of the lugworm *Arenicola marina*. *Netherlands Journal of Sea Research*, **30**, 81-89.

Folk, R.L., 1954. The distinction between grain size and mineral composition in sedimentary-rock nomenclature. **62**, *The Journal of Geology*, 344-359.

Fowler, S.L., 1999. Guidelines for managing the collection of bait and other shoreline animals within UK European marine sites. *Natura 2000 report prepared by the Nature Conservation Bureau Ltd. for the UK Marine SACs Project,* 132 pp., Peterborough: English Nature (UK Marine SACs Project)., http://www.english-nature.org.uk/uk-marine/reports/reports.htm

Freire-Santos, F., Oteiza-Lopez, A.M., Vergara-Castablanco, C.A., Ares-Mazas, E., Alvarez-Suarez, E. & Garcia-Martin, O., 2000. Detection of *Cryptosporidium* oocysts in bivalve molluscs destined for human consumption. *Journal of Parasitology*, **86**, 853-854.

Fretter, V. & Graham, A., 1981. The Prosobranch Molluscs of Britain and Denmark. Part 6. olluscs of Britain and Denmark. part 6. *Journal of Molluscan Studies*, Supplement 9, 309-313.

Gibbs, P.E., 1971. Reproductive cycles in four polychaete species belonging to the family Cirratulidae. *Journal of the Marine Biological Association of the United Kingdom*, **51**, 745-769.

Giere, O., 2006. Ecology and biology of marine oligochaeta–an inventory rather than another review. *Hydrobiologia*, **564** (1), 103-116.

Giere, O. & Pfannkuche, O., 1982. Biology and ecology of marine Oligochaeta, a review. *Oceanography and Marine Biology*, **20**, 173-309.

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

Grant, J. & Thorpe, B., 1991. Effects of suspended sediment on growth, respiration, and excretion of the soft shelled clam (*Mya arenaria*). *Canadian Journal of Fisheries and Aquatic Sciences*, **48**, 1285-1292.

Hall, S.J. & Harding, M.J.C., 1997. Physical disturbance and marine benthic communities: the effects of mechanical harvesting of cockles on non-target benthic infauna. *Journal of Applied Ecology*, **34**, 497-517.

Hall, S.J., 1994. Physical disturbance and marine benthic communities: life in unconsolidated sediments. *Oceanography and Marine Biology: an Annual Review*, **32**, 179-239.

Hartnoll, R.G. & Hawkins, S.J., 1980. Monitoring rocky shore communities: a critical look at spatial and temporal variation. *Helgolander Meeresuntersuchungen*, **33**, 484-495.

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

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

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

Jara-Jara, R., Abad, M., Pazos, A.J., Perez-Paralle, M.L. & Sanchez, J.L., 2000. Growth and reproductive patterns in *Venerupis pullastra* seed reared in waste water effluent from a fish farm in Galicia (N.W. Spain). *Journal of Shellfish Research*, **19**, 949-956.

JNCC, 2015. The Marine Habitat Classification for Britain and Ireland Version 15.03. JNCC: JNCC. 2015(20/05/2015). jncc.defra.gov.uk/MarineHabitatClassification

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

Johannessen, O.H., 1973b. Population structure and individual growth of *Venerupis pullastra* (Montagu) (Lamellibranchia). *Sarsia*, **52**, 97-116.

Johnston, R., 1984. Oil Pollution and its management. In *Marine Ecology: A Comprehensive, Integrated Treatise on Life in the Oceans and Coastal Waters* vol. 5. *Ocean Management*, part 3 (ed. O. Kinne), pp.1433-1582. New York: John Wiley & Sons Ltd.

Jorgensen, B.B., 1980. Seasonal oxygen depletion in the bottom waters of a Danish fjord and its effect on the benthic community. *Oikos*, **32**, 68-76.

Kaiser, M.J. & Spencer, B.E., 1995. Survival of by-catch from a beam trawl. *Marine Ecology Progress Series*, **126**, 31-38.

Kaschl, A. & Carballeira, A., 1999. Behavioural responses of *Venerupis decussata* (Linnaeus, 1758) and *Venerupis pullastra* (Montagu, 1803) to copper spiked marine sediments. *Boletin. Instituto Espanol de Oceanografia*, **15**, 383-394.

Kinne, O. (ed.), 1984. *Marine Ecology: A Comprehensive, Integrated Treatise on Life in Oceans and Coastal Waters.*Vol. V. *Ocean Management Part 3: Pollution and Protection of the Seas - Radioactive Materials, Heavy Metals and Oil.* Chichester: John Wiley & Sons.

Landsberg, J.H., 1996. Neoplasia and biotoxins in bivalves: is there a connection? *Journal of Shellfish Research*, **15**, 203-230.

Lange, R., 1972. Some recent work on osmotic, ionic and volume regulation in marine animals. *Oceanography and Marine Biology: an Annual Review*, **10**, 97-136.

Levell, D., 1976. The effect of Kuwait Crude Oil and the Dispersant BP 1100X on the lugworm, *Arenicola marina* L. In *Proceedings of an Institute of Petroleum / Field Studies Council meeting, Aviemore, Scotland, 21-23 April 1975. Marine Ecology and Oil Pollution* (ed. J.M. Baker), pp. 131-185. Barking, England: Applied Science Publishers Ltd.

Linke, O., 1939. Die Biota des Jadebusenwatts. *Helgolander Wissenschaftliche Meeresuntersuchungen*, **1**, 201-348.

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

Lopez-Flores I., De la Herran, R., Garrido-Ramos, M.A., Navas, J.I., Ruiz-Rejon, C. & Ruiz-Rejon, M., 2004. The molecular diagnosis of *Marteilia refringens* and differentiation between *Marteilia* strains infecting oysters and mussels based on the rDNA IGS sequence. *Parasitology*, **19** (4), 411-419.

MacDonald, J. A. & Storey, K. B., 1999. Cyclic AMP-dependent protein kinase: role in anoxia and freezing tolerance of the marine periwinkle *Littorina littorea*. *Marine Biology*, **133**, 193-203.

Maurer, D., Keck, R.T., Tinsman, J.C., Leatham, W.A., Wethe, C., Lord, C. & Church, T.M., 1986. Vertical migration and mortality of marine benthos in dredged material: a synthesis. *Internationale Revue der Gesamten Hydrobiologie*, **71**, 49-63.

McCall, P.L., 1977. Community patterns and adaptive strategies of the infaunal benthos of Long Island Sound. *Journal of Marine Research*, **35**, 221-266.

McLaughlin, S.M. & Faisal, M., 2000. *In vitro* propagation of two *Perkinsus* species from the softshell clam *Mya arenaria.*. *Journal de la Societe Francaise de Parasitologie*, **7**, (summary only).

Meire, P.M., 1993. The impact of bird predation on marine and estuarine bivalve populations: a selective review of patterns and underlying causes. In *Bivalve filter feeders in estuarine and coastal ecosystem processes* (ed. R.F. Dame). NATO ASI Series, Springer Verlag.

Navarro, J.M. & Widdows, J., 1997. Feeding physiology of *Cerastoderma edule* in response to a wide range of seston concentrations. *Marine Ecology Progress Series*, **152,** 175-186.

Navas, J.I., Castillo, M.C., Vera, P. & Ruiz-Rico, M., 1992. Principal parasites observed in clams, *Ruditapes decussatus* (L.), *Ruditapes philippinarum* (Adam et Reeve), *Venerupis pullastra* (Montagu) and *Venerupis aureus* (Gmelin) from the Huelva coast (SW Spain). *Aquaculture*, **107**, 193-199.

Olafsson, E.B. & Persson, L.E., 1986. The interaction between *Nereis diversicolor* (Muller) and *Corophium volutator* (Pallas) as a structuring force in a shallow brackish sediment. *Journal of Experimental Marine Biology and Ecology*, **103**, 103-117.

Olafsson, E.B., Peterson, C.H. & Ambrose, W.G. Jr., 1994. Does recruitment limitation structure populations and communities of macro-invertebrates in marine soft sediments: the relative significance of pre- and post-settlement processes. *Oceanography and Marine Biology: an Annual Review*, **32**, 65-109

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

Perez Camacho, A., 1980. Biology of *Venerupis pullastra* (Montagu, 1803) and *Venerupis decussata* (Linne, 1767) (Mollusca, Bivalvia). Determining factors of production. *Boletin del Instituto Espanol Oceanographica*, **5**, 43-76.

Picton, B.E. & Costello, M.J., 1998. *BioMar* biotope viewer: a guide to marine habitats, fauna and flora of Britain and Ireland. [CD-ROM] *Environmental Sciences Unit, Trinity College, Dublin.*

Powilleit, M., Graf, G., Kleine, J., Riethmuller, R., Stockmann, K., Wetzel, M.A. & Koop, J.H.E., 2009. Experiments on the survival of six brackish macro-invertebrates from the Baltic Sea after dredged spoil coverage and its implications for the field. *Journal of Marine Systems*, **75** (3-4), 441-451.

Price, H., 1982. An analysis of factors determining seasonal variation in the byssal attachment strength of *Mytilus edulis*. *Journal of the Marine Biological Association of the United Kingdom*, **62** (01), 147-155

Raffaelli, D. & Hawkins, S., 1999. *Intertidal Ecology* 2nd edn.. London: Kluwer Academic Publishers.

Rees, E.I.S., Nicholaidou, A. & Laskaridou, P., 1977. The effects of storms on the dynamics of shallow water benthic associations. In *Proceedings of the 11th European Symposium on Marine Biology, Galway, Ireland, October 5-11, 1976. Biology of Benthic Organisms, (ed. B.F. Keegan, P. O'Ceidigh & P.J.S. Boaden), pp. 465-474.*

Rees, H.L. & Dare, P.J., 1993. Sources of mortality and associated life-cycle traits of selected benthic species: a review. *MAFF Fisheries Research Data Report, no. 33.*, Lowestoft: MAFF Directorate of Fisheries Research.

Reise, K., 1985. *Tidal flat ecology. An experimental approach to species interactions.* Springer-Verlag, Berlin.

Rhoads, D.C. & Young, D.K., 1970. The influence of deposit-feeding organisms on sediment stability and community trophic structure. *Journal of Marine Research*, **28**, 150-178.

Riedel, B., Zuschin, M. & Stachowitsch, M., 2012. Tolerance of benthic macrofauna to hypoxia and anoxia in shallow coastal seas: a realistic scenario. *Marine Ecology Progress Series*, **458**, 39-52.

Riera, R., Tuya, F., Ramos, E., Rodríguez, M. & Monterroso, Ó., 2012. Variability of macrofaunal assemblages on the surroundings of a brine disposal. *Desalination*, **291**, 94-100.

Rosenberg, R. & Loo, L., 1988. Marine eutrophication induced oxygen deficiency: effects on soft bottom fauna, western Sweden. *Ophelia*, **29**, 213-225.

Rosenberg, R., Hellman, B. & Johansson, B., 1991. Hypoxic tolerance of marine benthic fauna. *Marine Ecology Progress Series*, **79**, 127-131.

Russell, P.J.C. & Petersen, G.H., 1973. The use of ecological data in the elucidation of some shallow water European *Cardium* species. *Malacologia*, **14**, 223-232.

Rygg, B., 1970. Studies on *Cerastoderma edule* (L.) and *Cerastoderma glaucum* (Poiret). *Sarsia*, **43**, 65-80.

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

SEEEC (*Sea Empress* Environmental Evaluation Committee), 1998. The environmental impact of the *Sea Empress* oil spill. *Final Report of the* Sea Empress *Environmental Evaluation Committee,* 135 pp., London: HMSO.

Sinderman, C.J., 1990. *Principle diseases of marine fish and shellfish, 2nd edition, Volume 2. Diseases of marine shellfish*. Academic Press, 521 pp.

Snelgrove, P.V.R. & Butman, C.A., 1994. Animal-sediment relationships revisited: cause versus effect. *Oceanography and Marine Biology: an Annual Review*, **32**, 111-177.

Stamouli, M. & Papadopoulou, C., 1990. Trivalent Cr-51 bioaccumulation study in two mollusc species. *Thalassographica. Athens*, **13** suppl. 1, 49-52.

Stenton-Dozey, J.M.E. & Brown, A.C., 1994. Short term changes in the energy balance of *Venerupis corrugatus* (Bivalvia) in relation to tidal availability of natural suspended particles. *Marine Ecology Progress Series*, **103**, 57-64.

Stirling, E.A., 1975. Some effects of pollutants on the behaviour of the bivalve *Tellina tenuis*. *Marine Pollution Bulletin*, **6**, 122-124.

Strasser, M., 1999. *Mya arenaria* - an ancient invader of the North Sea coast. *Helgoländer Meeresuntersuchungen*, **52**, 309-324.

Strömgren, T., 1979a. The effect of copper on the increase in length of *Ascophyllum nodosum*. *Journal of Experimental Marine Biology and Ecology*, **37**, 153-159.

Strömgren, T., 1979b. The effect of zinc on the increase in length of five species of intertidal Fucales. *Journal of Experimental Marine Biology and Ecology*, **40**, 95-102.

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

UKTAG, 2014. UK Technical Advisory Group on the Water Framework Directive [online]. Available from: http://www.wfduk.org

Van Hoey, G., Guilini, K., Rabaut, M., Vincx, M. & Degraer, S., 2008. Ecological implications of the presence of the tube-building polychaete *Lanice conchilega* on soft-bottom benthic ecosystems. *Marine Biology*, **154** (6), 1009-1019.

Waugh, G.D., 1964. Effect of severe winter of 1962-63 on oysters and the associated fauna of oyster grounds of southern England. *Journal of Animal Ecology*, **33**, 173-175.

Widdows, J., Bayne, B.L., Livingstone, D.R., Newell, R.I.E. & Donkin, P., 1979. Physiological and biochemical responses of bivalve molluscs to exposure to air. *Comparative Biochemistry and Physiology*, **62A**, 301-308.

Yaroslavsteva, L.M. & Fedoseeva, S.V., 1978. Adaptation of some marine mollusks to estuarine habitats. *Soviet Journal of Marine Biology*, **4**, 820-826.

Zebe, E. & Schiedek, D., 1996. The lugworm *Arenicola marina*: a model of physiological adaptation to life in intertidal sediments. *Helgoländer Meeresuntersuchungen*, **50**, 37-68.