Polydora ciliata and *Corophium volutator* in variable salinity infralittoral firm mud or clay

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

Eliane De-Bastos & Jacqueline Hill

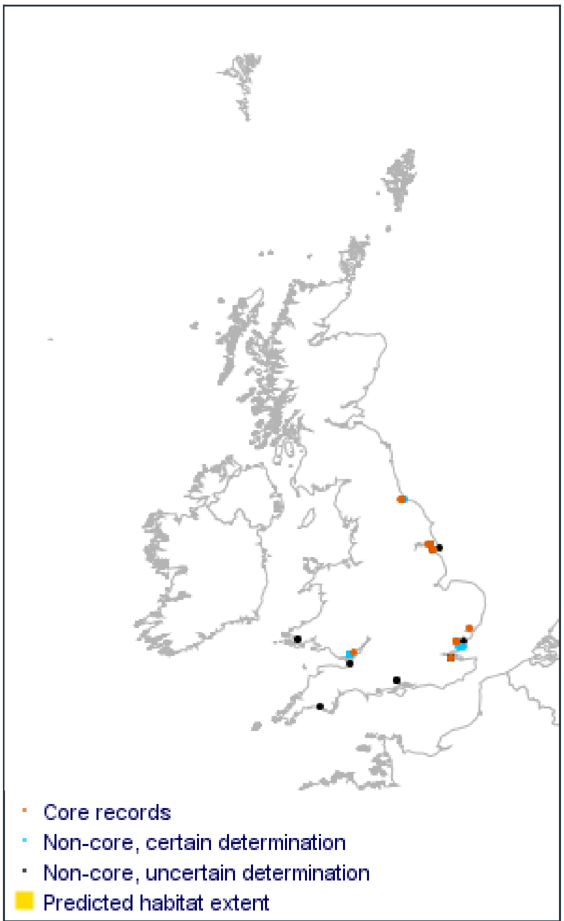
2016-06-19

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/193]. All terms and the MarESA methodology are outlined on the website (https://www.marlin.ac.uk)

This review can be cited as:
De-Bastos, E.S.R. & Hill, J., 2016. [Polydora ciliata] and [Corophium volutator] in variable salinity infralittoral firm mud or clay. 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.

(page left blank)



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

Researched by Eliane De-Bastos & Jacqueline Hill **Refereed by** This information is not refereed.

Summary

UK and Ireland classification

EUNIS 2008	A5.321	*Polydora ciliata* and *Corophium volutator* in variable salinity infralittoral firm mud or clay
JNCC 2015	SS.SMu.SMuVS.PolCvol	*Polydora ciliata* and *Corophium volutator* in variable salinity infralittoral firm mud or clay
JNCC 2004	SS.SMu.SMuVS.PolCvol	*Polydora ciliata* and *Corophium volutator* in variable salinity infralittoral firm mud or clay
1997 Biotope	SS.IMU.EstMu.PolVS	*Polydora ciliata* in variable salinity infralittoral firm mud or clay

Description

Variable salinity clay and firm mud characterized by a turf of the polychaete *Polydora ciliata* along with the amphipod *Corophium volutator*. Other important taxa include the polychaetes *Pygospio* *elegans*, *Hediste diversicolor*, *Streblospio shrubsolii* and the oligochaete *Tubificoides benedii*. *Polydora ciliata* also occurs in high densities elsewhere (see CR.MCR.SfR.Pol) and may be a specific feature of the Humber Estuary in these conditions. This biotope occurs only in very firm mud and clay and possibly submerged relict saltmarsh with a high detrital content. It is characterized, and can be separated from other biotopes, by a combination of the sediment characteristics and the very high density of *Polydora ciliata*. In some areas, such as the Humber estuary, cyclical behaviour with regard its characteristic taxa has been reported with either *Polydora ciliata* or *Corophium volutator* increasing in dominance at the expense of the other (Gameson, 1982). It is possible that changes in water quality or the sediment regime may be responsible for this. (Information taken from Connor *et al.*, 2004).

Depth range

0-5 m, 5-10 m

Additional information

None entered

Listed By

- none -

Further information sources

Search on:

G G G JNCC

Habitat review

Ecology

Ecological and functional relationships

- In areas of mud, the tubes built by *Polydora ciliata* can agglomerate and form layers up to an average of 20 cm thick, occasionally to 50 cm. These mud layers can eliminate the original fauna and flora, or at least can be considered as a threat to the ecological balance achieved by some biotopes (Daro & Polk, 1973).
- Daro & Polk (1973) state that the formation of layers of *Polydora ciliata* tend to eliminate original flora and fauna. The species readily overgrows other species with a flat morphology and feeds by scraping its palps outside its tubes, which would inhibit the development of settling larvae of other species.
- The activities of *Polydora* plays an important part in the process of temporary sedimentation of muds in some estuaries, harbours or coastal areas (Daro & Polk, 1973).
- Other species that may be found in the biotope include mud dwelling polychaetes such as the slow moving, burrowing *Pholoe synophthalmica* and mucus tube building *Neoamphitrite figulus*. The amphipod *Corophium volutator*, which builds semi-permanent burrows in mud may also be present in high abundance.

Seasonal and longer term change

- The early reproductive period of *Polydora ciliata* often enables the species to be the first in the year to colonize available substrata (Green, 1983). The settling of the first generation in April is followed by the accumulation and active fixing of mud continuously up to a peak during the month of May, when the substrata is covered with the thickest layer of *Polydora* mud. The following generations do not produce a heavy settlement due to interspecific competition and heavy mortality of the larvae (Daro & Polk, 1973).
- Later in the year, the surface layer of substantial *Polydora* muds may not be able to hold the lower layers of the mud mat in place, they crumble away and are then swept away by water currents. The empty tubes of *Polydora* may saturate the sea close to dense *Polydora ciliata* aggregations in June. Recolonization of the substratum is made possible when larva of other species are in the plankton, so recolonization by *Polydora* may not be as successful as earlier in the year.

Habitat structure and complexity

The biotope has very little structural complexity as *Polydora* tubes aggregate to dominate firm mud or clay. *Polydora* mats tend to be single species providing little space for other fauna or flora. A *Polydora* mud is about 20 cm thick, but can be up to 50 cm thick.

Productivity

- Productivity in IMU.PolVS is mostly secondary, derived from detritus and organic material. *Polydora ciliata* generally feeds on detritus but may also suspension feed on particles in the water. Macroalgae are absent from the biotope.
- The biotope often occurs in nutrient rich areas, for example, close to sewage outfalls. Allochthonous organic material is derived from anthropogenic activity (e.g. sewerage) and natural sources (e.g. plankton, detritus). Autochthonous organic material is formed by

benthic microalgae (microphytobenthos e.g. diatoms and euglenoids) and heterotrophic micro-organism production. Organic material is degraded by micro-organisms and the nutrients are recycled. The high surface area of fine particles that covers the *Polydora* mud provides surface for microflora.

Recruitment processes

The spawning period for *Polydora ciliata* in northern England is from February until June and three or four generations succeed one another during the spawning period (Gudmundsson, 1985). After a week of development the larvae emerge and are believed to have a pelagic life from two to six weeks before settling (Fish & Fish, 1996). Larvae are substratum specific selecting rocks according to their physical properties or sediment depending on particle size. Larvae of *Polydora ciliata* have been collected as far as 118 km offshore (Murina, 1997). Adults of *Polydora ciliata* produce a 'mud' resulting from the perforation of soft rock substrata and the larvae of the species settle preferentially on substrata covered with mud (Lagadeuc, 1991).

Time for community to reach maturity

A *Polydora* biotope is likely to reach maturity very rapidly because *Polydora ciliata* is a short lived species that reaches maturity within a few months and has three or four spawnings during a breeding season of several months. For example, in colonization experiments in Helgoland (Harms & Anger, 1983), *Polydora ciliata* settled on panels within one month in the spring. The tubes built by *Polydora* sometimes agglomerate to form layers of mud up to an average of 20 cm thick. However, it may take several years for a *Polydora ciliata* 'mat' to reach a significant size.

Additional information

None

Preferences & Distribution

Habitat preferences

Depth Range	0-5 m, 5-10 m
Water clarity preferences	
Limiting Nutrients	Not relevant
Salinity preferences	
Physiographic preferences	
Biological zone preferences	
Substratum/habitat preferences	
Tidal strength preferences	
Wave exposure preferences	
Other preferences	Mud, clay or soft rock substratum

Additional Information

Polydora ciliata is only found in areas of soft rock, such as limestone and chalk, and firm muds and clay where it can make its burrows.

Species composition

Species found especially in this biotope

Rare or scarce species associated with this biotope

-

Additional information

None

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

SS.SMu.SMuVS.PolCvol is a sublittoral biotope occurring in sheltered, very sheltered and extremely sheltered areas with weak tidal streams (Connor *et al.*, 2004). The biotope occurs in variable salinity and exclusively in clay and very firm mud, and is characterized by a turf of the polychaete *Polydora ciliata* along with the amphipod *Corophium volutator*. It may also occur in submerged relict saltmarsh with a high detrital content. Other important taxa include the polychaetes *Pygospio elegans*, *Hediste diversicolor*, *Streblospio shrubsolii* and the oligochaete *Tubificoides benedii*. In some areas, such as the Humber Estuary, cyclical behaviour regarding its characteristic taxa has been reported with either *Polydora ciliata* or *Corophium volutator* increasing in dominance at the expense of the other (Gameson, 1982). It is possible that changes in water quality or the sediment regime may be responsible for this. *Polydora ciliata* also occurs in high densities elsewhere (see CR.MCR.SfR.Pol). Because of their high numbers, *Corophium volutator* are thought to stabilize the intertidal sediments in which they reside (Mouritsen *et al.*, 1998). The biotope is characterized, and can be separated from other biotopes, by a combination of the sediment characteristics and the very high density of *Polydora ciliata* occurring along with *Corophium volutator*. Therefore, *Polydora ciliata* and *Corophium volutator* are the focus of this sensitivity assessment.

Resilience and recovery rates of habitat

Polyodra spp. is a small, sedentary, burrowing polychaete worm up to 3 cm long. All *Polydora* spp. make a U-shaped tube from small particles (Hayward & Ryland, 1995b). *Polydora ciliata* usually burrows into substrata containing calcium carbonate such as limestone, chalk and clay, as well as shells or oysters, mussels and periwinkles (Fish & Fish, 1996). The sexes are separate and breeding has been recorded in spring in a number of locations. In northern England, it has been recorded to occur from February until June and three or four generations succeed one another during the spawning period (Gudmundsson, 1985). Eggs are laid in a string of capsules that are attached by two threads to the wall of the burrow (Fish & Fish, 1996). After a week the larvae emerge and are believed to have a pelagic life of 2-6 weeks before settling. Length of life is no more than 1 year (Fish & Fish, 1996). Almeda *et al.* (2009) suggested low filtration rates and low growth rates despite high food availability for *Polydora ciliata* larvae, which suggested a compromise to ensure efficient larval dispersion. Larvae are substratum specific, selecting rocks according to their physical properties or sediment depending on particle size. Larvae of *Polydora ciliata* have been collected as far as 118 km offshore (Murina, 1997). Adults of *Polydora ciliata* produce a 'mud' resulting from the perforation of soft rock substrata and the larvae of the species settle preferentially on substrata covered with mud (Lagadeuc, 1991).

A *Polydora* biotope is likely to reach maturity very rapidly because *Polydora ciliata* is a short lived species that reaches maturity within a few months and has three or four spawnings during a breeding season of several months. The early reproductive period of *Polydora ciliata* often enables the species to be the first to colonize available substrata (Green, 1983). For example, in colonization experiments in Helgoland (Harms & Anger, 1983), *Polydora ciliata* settled on panels within one month in the spring. The tubes built by *Polydora* sometimes agglomerate to form layers of mud up to an average of 20 cm thick.

The settling of the first generation in April is followed by the accumulation and active fixing of mud continuously up to a peak during the month of May. The following generations do not produce a heavy settlement due to interspecific competition and heavy mortality of the larvae (Daro & Polk, 1973). Later in the year, the surface layer cannot hold the lower layers of the mud mat in place. They crumble away and are then swept away by water currents. The empty tubes of *Polydora* may saturate the sea in June.

Corophium volutator is a mud shrimp with a long slender body up to 11 mm in length. The amphipod occupies semi-permanent U-shaped burrows up to 5 cm deep (Meadows & Reid, 1966) in the fine sediments of mud flats, saltmarsh pools and brackish ditches. It lives for a maximum of one year (Hughes, 1988) and females can have 2-4 broods in a lifetime (Conradi & Depledge, 1999). Populations in southerly areas such as the Dovey Estuary, Wales or Starrs Point, Nova Scotia have two reproductive episodes per year. Those populations in colder, more northerly areas such as the Ythan Estuary, Scotland or in the Baltic Sea only have one (Wilson & Parker, 1996).

On the west coast of Wales, breeding takes places from April to October and mating takes place in the burrow. Adult males crawl over the surface of the moist sediment as the tide recedes in search of burrows occupied by mature females. *Corophium volutator* forms an important food source for several species of birds and mobile predators such as fish and crabs (Hughes, 1988; Jensen & Kristensen, 1990; Raffaelli *et al*., 1991; Flach & De Bruin, 1994; Brown *et al*., 1999), so this behaviour makes them vulnerable to predation (Fish & Mills, 1979; Hughes, 1988; Forbes *et al*., 1996). The females can produce 20-52 embryos in each reproductive episode (Fish & Mills 1979; Jensen & Kristensen, 1990). Juveniles are released from the brood chamber after about 14 days, and development is synchronized with spring tides, possibly to aid dispersal. Recruitment occurs within a few centimetres of the parent, although they may disperse later by swimming (Hughes, 1988). In the warmer regions where *Corophium volutator* is found, juveniles can mature in 2 months (Fish & Mills, 1979) and add their own broods to the population. The juveniles born in May undergo rapid growth and maturation to reproduce from July to September and generate the next overwintering population (Fish & Mills, 1979).

Corophium volutator is one of the most abundant organisms in estuarine mudflats reaching densities of 100,000 m^{-2} in the Stour Estuary, Suffolk (Hughes, 1988). Densities vary with geographical region and season, having been reported to rise considerably during the summer months in Gullmarsfjorden, Wadden Sea, and in the Crouch Estuary in southeast England (Flach & De Bruin, 1993; Gerdol & Hughes, 1993).

Resilience assessment: Removal of the characterizing species *Polydora ciliata* and *Corophium volutator* would result in the biotope being lost and/or re-classified. Both species are known to have long reproductive seasons during their short lifespans. Where perturbation removes a portion of the population or even causes local extinction (resistance High, Medium or Low) resilience is likely to be **High** for as long as recruitment from neighbouring areas and/or adult migration is possible. However, even in areas of suitable habitat that are isolated, where total extinction of the population occurs (resistance None) recovery is likely to depend on favourable hydrodynamic conditions that will allow recruitment from farther away. Given the low energy environment where the biotope occurs, recruitment to re-colonize impacted area may take longer. However, once an area has been recolonized, restoration of the biomass of both characterizing species is likely to occur quickly and resilience is likely to be **Medium** (full recovery within 2-10 years).

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

Hydrological Pressures

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

Murina (1997) categorized *Polydora ciliata* as an eurythermal species because of its ability to spawn in temperatures ranging from 10.6-19.9°C. This is consistent with a wide distribution in north-west Europe, which extends into the warmer waters of Portugal and Italy (Pardal *et al.*, 1993; Sordino *et al.*, 1989). In the western Baltic Sea, Gulliksen (1977) recorded high abundances of *Polydora ciliata* in temperatures of 7.5 to 11.5°C and in Whitstable in Kent sea temperatures varied between 0.5 and 17°C (Dorsett, 1961). Growth rates may increase if temperature rises. For example, at Whitstable in Kent, Dorsett (1961) found that a rapid increase in growth coincided with the rising temperature of the seawater during March.

Corophium volutator is equally widely distributed in the north Atlantic, American and European coasts; from western Norway to the Mediterranean and the Black Sea and Azov Sea (Neal & Avant, 2006). The amphipod is subject to temperatures of 1°C in the winter to 17°C in the summer (Wilson & Parker, 1996) but can resist much higher temperatures (Meadows & Ruagh, 1981).

Sensitivity assessment: It is likely that the characterizing species of this biotope are able to resist a long-term increase in temperature of 2°C and may resist a short-term increase of 5°C. Resistance and resilience are therefore assessed as **High** and the biotope assessed as **Not Sensitive** at the benchmark level.

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

Murina (1997) categorized *Polydora ciliata* as an eurythermal species because of its ability to spawn in temperatures ranging from 10.6-19.9°C. This is consistent with a wide distribution in north-west Europe. In the western Baltic Sea, Gulliksen (1977) recorded high abundances of *Polydora ciliata* in temperatures of 7.5 to 11.5°C and in Whitstable in Kent abundance was high when winter water temperatures dropped to 0.5°C (Dorsett, 1961). During the extremely cold winter of 1962/63 *Polydora ciliata* was apparently unaffected (Crisp, 1964).

Corophium volutator is subject to temperatures of 1°C in the winter to 17°C in the summer (Wilson & Parker, 1996). The population may reduce activity and delay reproduction if the temperature drops below 7°C. Sudden pulses of very cold water can disrupt the circa-tidal rhythms of *Corophium volutator* by resetting the onset of swimming behaviour. For example, a 6 hour cold spell would lead to the population trying to swim at low tide and leave them vulnerable to increased predation. However, it took temperatures of 15-20°C below ambient temperature to induce this response (Holmström & Morgan, 1983b).

Drolet *et al.* (2013) sampled two intertidal mudflats in the upper Bay of Fundy, Canada, over two consecutive winters (2009–2011), where sediment temperature, 5 cm deep, reached ▯2°C. The authors concluded *Corophium volutator* survived winter through physiological adaptations.

Sensitivity assessment: The characterizing species of this biotope are likely to be able to resist a long-term decrease in temperature of 2°C and may resist a short-term decrease of 5°C. Resistance and resilience are therefore assessed as **High** and the biotope judged as **Not Sensitive** at the benchmark level.

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

Polydora ciliata is an euryhaline species inhabiting fully marine and estuarine habitats. However, there are no records of the species or the biotope occurring in hypersaline waters.

Corophium volutator is an exceptionally euryhaline species able to tolerate 2-50 psu (McLusky, 1968) but growth is fastest at 15-20 psu (McLusky, 1967; McLusky, 1970 cited in Meadows & Ruagh, 1981). The interstitial salinity is more important for *Corophium volutator* than that of the overlying water and there is no ready exchange of water and solutes between the two. Sustained periods of increased salinity are required to alter that of the interstitial water and there is a lag between salinity changes and the response of *Corophium volutator* (McLusky, 1968). Salinity is thought to entrain *Corophium volutator* to the tides and sudden increases in salinity delay swimming activity (Harris & Morgan, 1984a). *Corophium volutator* will emigrate from areas of unfavourable salinity (McLusky, 1968).

Sensitivity assessment: The characterizing species of this biotope are euryhaline and likely to be resistant of an increase in salinity. However, a chronic increase at the pressure benchmark level that remains over time is likely to result in the death of a portion of the individuals in the population, particularly of *Polydora ciliata* due to its inability to move to more favourable conditions. Resistance is therefore assessed as **Low** and resilience is likely to be **High** so the biotope is considered to have **Low** sensitivity to an increase in salinity at the pressure benchmark level.

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

Polydora ciliata is an euryhaline species inhabiting fully marine and estuarine habitats. In an area of the western Baltic Sea, where bottom salinity was between 11.1 and 15.0 psu, *Polydora ciliata* was the second most abundant species with over 1000 individuals per m^2 (Gulliksen, 1977).

Corophium volutator is an exceptionally euryhaline species able to tolerate 2-50 psu (McLusky, 1968) but growth is fastest at 15-20 psu (McLusky, 1970 cited in Meadows & Ruagh, 1981). *Corophium volutator* is a hyperosmotic regulator and the tolerance of its tissues is 13-50 psu but it needs a salinity of above 5 psu in order to moult, since osmoregulation is lost during moulting (McLusky, 1967). A salinity of at least 7.5 psu is required for reproduction (McLusky, 1968). Changes in salinity may alter population distribution and dynamics as the species is likely to move to more favourable conditions but are very unlikely to cause mortality.

Sensitivity assessment: Records indicate SS.SMu.SMuVS.PolCvol occurs in areas of variable (18-35 ppt) salinity, with records of the biotope also occurring in reduced to low salinities (Connor *et al.*, 2004). Both characterizing species, *Polydora ciliata* and *Corophium volutator*, are therefore likely to resist a decrease in salinity at the pressure benchmark level. Resistance is therefore assessed as **High** and resilience as **High** (by default) and the biotope is assessed as **Not Sensitive** to a decrease in salinity at the pressure benchmark level.

Water flow (tidal current) changes (local)	Low Q: Medium A: Low C: High	High Q: High A: Medium C: High	Low Q: Medium A: Low C: High

Polydora ciliata was present and colonized test panels in Helgoland in three areas; two exposed to strong tidal currents and one site sheltered from currents (Harms & Anger, 1983). However, in very strong tidal currents little sediment deposition will take place, resulting in coarse sediments with little organic matter. As a result the sediment may become unsuitable for the deposit feeding and tube building activities of *Polydora ciliata*. But where suspended sediment levels are high, deposition of fine sediment may occur even in strong flows providing suitable conditions for the species. Very strong water flows may sweep away *Polydora* colonies, often in a thick layer of mud on a hard substratum.

Small *Corophium volutator* cannot resettle after swimming at current speeds approx. 0.1 m/s (Ford & Paterson, 2001), which probably explains why they mainly swim at high tide (Hughes, 1988). An increase in water flow rate could cause swimming *Corophium volutator* to be swept away from suitable habitat and cause high mortality. Decreases in flow rate are not considered to negatively impact *Corophium volutator*. The species has been reported as not using flow velocity as a cue to stimulate swimming (Ford & Paterson, 2001).

The most damaging effect of increased flow rate would be the erosion of the firm mud or clay substratum as this could eventually lead to loss of the habitat. Emergent species, such as the *Polydora ciliata* tubes that characterize this biotope, may create turbulent flow leading to particle re-suspension. However, clay offers increased cohesiveness and resistance to erosion and, because of their high numbers, amphipods are thought to stabilize the intertidal sediments in which they reside (Mouritsen *et al.*, 1998).

Sensitivity assessment: Sand particles are most easily eroded and likely to be eroded at about 0.20 m/s (based on Hjulström-Sundborg diagram, Sundborg, 1956). Although having a smaller grain size than sand, clays and silts require greater critical erosion velocities because of their cohesiveness. SS.SMu.SMuVS.PolCvol is recorded only in weak (>0.5 m/s) tidal streams (Connor *et al.*, 2004). A decrease in water flow is unlikely to cause any impact on the biotope as species are adapted to incremental deposition. However, an increase in water flow at the pressure benchmark is likely to result in loss of the characterizing species *Corophium volutator*, as it has been reported to not be able to settle from swimming at flow as low as 0.1 m/s (Ford & Paterson, 2001). Resistance is therefore assessed as **Low** and resilience as **High** and the biotope judged as having **Low** sensitivity to a change in water flow at the pressure benchmark level.

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

SS.SMu.SMuVS.PolCvol occurs in the shallow subtidal fringe and a change in emergence could potentially affect the extreme fringes of the biotope. However, changes in emergence are **Not**

Relevant to the biotope, which is restricted to fully subtidal/circalittoral conditions.

	Resistance	Resilience	Sensitivity
Wave exposure changes (local)	High Q: Medium A: Low C: High	High Q: High A: High C: High	Not sensitive Q: Medium A: Low C: High

The biotope is found in sheltered, very sheltered and extremely sheltered sites (Connor *et al.*, 2004). Feeding of *Polydora ciliata* and *Corophium volutator* may be impaired in strong wave action and changes in wave exposure may also influence the supply of particulate matter for tube building *Polydora*. Decreases in wave exposure may influence the supply of particulate matter because wave action may have an important role in re-suspending the sediment that is required by the species to build its tubes. Food supplies may also be reduced, affecting growth and fecundity of the species.

Potentially the most damaging effect of increased wave heights would be the erosion of the firm mud or clay substrata as this could eventually lead to loss of the habitat. Increased wave action may disturb the mud in which *Corophium volutator* lives and make it impossible for them to maintain burrows and may affect their ability to settle after swimming. Increased erosion would lead to the loss of habitat and removal of the characterizing species.

Sensitivity assessment: Some erosion will occur naturally and storm events may be more significant in loss and damage of clays. The biotope occurs in sheltered, very sheltered and extremely sheltered conditions (Connor *et al.*, 2004), and a change at the benchmark level is likely to fall within the range experienced by the mid-range examples of this biotope. The biotope is therefore considered to have **High** resistance to changes at the pressure benchmark where these do not lead to increased erosion of the substratum. Resilience is therefore assessed as **High** and the biotope is considered to be **Not Sensitive**, at the pressure benchmark.

Chemical Pressures

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

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

Experimental studies with various species suggest that polychaete worms are quite resistant to heavy metals (Bryan, 1984). *Polydora ciliata* occurs in an area of the southern North Sea polluted by heavy metals but was absent from sediments with very high heavy metal levels (Diaz-Castaneda *et al.*, 1989).

Corophium volutator is highly intolerant of metal pollution at levels often found in estuaries from industrial outfalls and contaminated sewage. A concentration of 38 mg Cu/l was needed to kill 50% of *Corophium volutator* in 96 hour exposures (Bat *et al.*, 1998). Other metals are far more toxic to *Corophium volutator*, e.g. zinc is toxic over 1 mg/l and toxicity to metals increases with increasing temperature and salinity (Bryant *et al.*, 1985). Mortality of 50% is caused by 14 mg/l (Bat *et al.*, 1998). Although exposure to zinc may not be lethal, it may affect the perpetuation of a population by reducing growth and reproductive fitness. Mercury was found to be very toxic to *Corophium volutator*, e.g. concentrations as low as 0.1 mg/l caused 50% mortality in 12 days. Other metals known to be toxic include cadmium, which causes 50% mortality at 12 mg/l (Bat *et al*., 1998), and arsenic, nickel and chromium which are all toxic over 2 mg/l (Bryant *et al*., 1984; Bryant *et al*., 1985a; 1985).

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.

In analysis of kelp holdfast fauna following the *Sea Empress* oil spill in Milford Haven the fauna present, including *Polydora ciliata*, showed a strong negative correlation between numbers of species and distance from the spill (SEEEC, 1998). After the extensive oil spill in West Falmouth, Massachusetts, Grassle & Grassle (1974) followed the settlement of polychaetes in the disturbed area. Species with the most opportunistic life histories, including *Polydora ligni*, were able to settle in the area. This species has some brood protection which enables larvae to settle almost immediately in the nearby area (Reish, 1979).

Light fractions (C10 - C19) of oils are much more toxic to *Corophium volutator* than heavier fractions (C19 - C40). In exposures of up to 14 days, light fraction concentrations of 0.1 g/kg sediment caused high mortality. It took 9 g/kg sediment to achieve similar mortalities with the heavy fraction (Brils *et al*., 2002). In the Forth Estuary, *Corophium volutator* was excluded for several hundred metres around the outfalls from hydrocarbon processing plants. Roddie *et al*. (1994) found high levels of mortality of *Corophium* at sites contaminated with crude oil.

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.

Polydora ciliata was abundant at polluted sites close to acidified, halogenated effluent discharge from a bromide-extraction plant in Amlwch, Anglesey (Hoare & Hiscock, 1974). Spionid polychaetes were found by McLusky (1982) to be relatively resistant of distilling and petrochemical industrial waste in Scotland.

Corophium volutator is paralysed by pyrethrum based insecticide sprayed onto the surface of the mud (Gerdol & Hughes, 1993) and pyrethrum would probably cause significant mortalities if it found its way into estuaries from agricultural runoff. Nonylphenol is an anthropogenic pollutant that regularly occurs in water bodies. It is an oestrogen mimic that is produced during the sewage treatment of non-ionic surfactants and can affect *Corophium volutator* (Brown *et al*., 1999). Nonylphenol is a hydrophobic molecule and often becomes attached to sediment in water bodies. This will make nonylphenol available for ingestion by *Corophium volutator* in estuaries where much of the riverine water-borne sediment flocculates and precipitates out of suspension to form mudflats. Nonylphenol is not lethal to *Corophium volutator* but does reduce growth and has the effect of causing the secondary antennae of males to become enlarged which can make the amphipods more vulnerable to predators (Brown *et al*., 1999). *Corophium volutator* is killed by 1% ethanol if exposed for 24 hours or more, but can withstand higher concentrations in short pulses. Such short pulses, however, have the effect of re-phasing the diel rhythm and will delay the timing of swimming activity for the duration of the ethanol pulse (Harris & Morgan, 1984b).

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

Corophium volutator readily absorbs radionuclides such as americium and plutonium from water and contaminated sediments (Miramand *et al*., 1982). However, the effect of contamination of the individuals was not known but accumulation through the food chain was assumed (Miramand *et al*., 1982).

There was **No Evidence** on which to base an assessment.

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

This pressure is **Not assessed**.

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

Polydora ciliata is repeatedly found at localities with oxygen deficiency (Pearson & Rosenberg, 1978). For example, in polluted waters in Los Angeles and Long Beach harbours *Polydora ciliata* was present in the oxygen range 0.0-3.9 mg/l and the species was abundant in hypoxic fjord habitats (Rosenberg, 1977). Furthermore, in a study investigating a polychaete community in the north west Black Sea, *Polydora ciliata* was observed in all four study sites, including those severely affected by eutrophication and hypoxia as a result of the discharge of waste waters (Vorobyova *et al*., 2008). However, *Polydora ciliata* is unlikely to be able to resist anoxic conditions. Hansen *et al.* (2002) reported near total extinction of all metazoan in the Mariager Fjord (Denmark), including *Polydora* spp. after a severe hypoxia event that resulted in complete anoxia in the water column for two weeks. Additionally, Como & Magni (2009) investigated seasonal variations in benthic communities known to be affected by episodic events of hypoxia. The authors observed that abundance of *Polydora ciliata* varied seasonally, decreasing during the summer months, and suggested it could be explained by the occurrence of hypoxic/anoxic conditions and sulphidic sediments during the summer. No details of the levels of dissolved oxygen leading to these community responses were provided.

Corophium volutator is highly sensitive to hypoxia and suffers 50% mortality after just 4 hours in hypoxic conditions, or in 2 hours if there is rapid build-up of sulphide (Gamenick *et al*., 1996). These conditions often occur in estuaries where drifting macroalgae (such as *Fucus* sp.) settle on the mudflats in small patches.

Sensitivity assessment: Cole *et al.* (1999) suggested possible adverse effects on marine species exposed to dissolved oxygen concentrations below 4 mg/l and probable adverse effects below 2 mg/l. *Polydora ciliata* is repeatedly found at localities with oxygen deficiency (Pearson & Rosenberg, 1978) and seems to only be affected by severe de-oxygenation episodes. Furthermore, opportunistic *Polydora* spp. were also reported to be amongst the first to recover from hypoxic events (Hansen *et al*., 2002; Van Colen *et al*., 2010). However, mortality of *Corophium volutator* is likely to occur. Resistance to de-oxygenation at the pressure benchmark level is likely to be **Low** and resilience is likely to be **High.** The biotope is therefore considered to have **Low** sensitivity to exposure to dissolved oxygen concentration of less than or equal to 2 mg/l for 1 week.

Nutrient enrichment	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not sensitive Q: NR A: NR C: NR

Polydora ciliata is often found in environments subject to high levels of nutrients. For example, the species was abundant in areas of the Firth of Forth exposed to high levels of sewage pollution (Smyth, 1968), in nutrient rich sediments in the Mondego estuary, Portugal (Pardal *et al.*, 1993) and the coastal lagoon Lago Fusaro in Naples (Sordino *et al.*, 1989). The extensive growths of *Polydora ciliata* in mat formations were recorded at West Ganton, in the Firth of Forth, prior to the introduction of the Sewage Scheme (Read *et al.*, 1983). The abundance of the species was probably associated with their ability to use the increased availability of nutrients as a food source and silt for tube building.

In the Ythan Estuary, Scotland, nutrient enrichment causes the mudflats to become covered with algal mats consisting mainly of the gutweed *Ulva intestinalis*. These mats physically perturb *Corophium volutator* by preventing burrowing and normal feeding. In areas where the mats did not occur, the density of *Corophium volutator* was 11 times higher than under the algae. When the algae died back in the winter, the areas were rapidly recolonized by *Corophium volutator* from adjacent patches where the gutweed could not grow and population growth was high from feeding on the rotting algae. In the spring, the gutweed returned and the *Corophium volutator* were excluded once again (Raffaelli *et al.*, 1991).

Sensitivity assessment: The characterizing species of this biotope are likely to be able to resist and be favoured by nutrient enrichment where increased availability of nutrients may be used as a source of food (Hiscock *et al.*, 2005a). However, where nutrient enrichment causes proliferation of algal mats, *Corophium volutator* densities are likely to be reduced as a result of smothering. Nevertheless, the biotope is considered **Not Sensitive** at the pressure benchmark that assumes compliance with good status as defined by the WFD.

Organic enrichment	Low Q: High A: Medium C: High	High Q: High A: Medium C: High	Low Q: High A: Medium C: High

Polydora ciliata is often found in environments subject to high levels of nutrients. For example, the species was abundant in areas of the Firth of Forth exposed to high levels of sewage pollution (Smyth, 1968), in nutrient rich sediments in the Mondego estuary, Portugal (Pardal *et al.*, 1993) and the coastal lagoon Lago Fusaro in Naples (Sordino *et al.*, 1989). The extensive growths of *Polydora ciliata* in mat formations were recorded at West Ganton, in the Firth of Forth, prior to the introduction of the Sewage Scheme (Read *et al.*, 1983). The abundance of the species was probably associated with their ability to use the increased availability of nutrients as a food source and silt for tube building. However, *Polydora ciliata* can also occur in organically poor areas (Pearson & Rosenberg, 1978).

In colonization experiments in an organically polluted fjord receiving effluent discharge from Oslo, *Polydora ciliata* had settled in large numbers within the first month (Green, 1983; Pardal *et al.*, 1993). However, Callier *et al.* (2007) investigated the spatial distribution of macrobenthos under a suspended mussel culture in eastern Canada, where the sedimentation of organic matter to the bottom was approx. 1-3 $gC/m^2/day$. *Polydora ciliata* was recorded as absent in the sites under the suspended mussel farm after one year and as dominant in reference areas of the study.

Como & Magni (2009) investigated seasonal variations in benthic communities known to be affected by episodic events of sediment over-enrichment. The authors observed that abundance of *Polydora ciliata* varied seasonally, and suggested this could be a result of major accumulation of organic carbon-binding fine sediments in the study site.

Studies by Almeda *et al.* (2009) and Pedersen *et al.* (2010) investigated larval energetic requirements for *Polydora ciliata*, and suggested maximum growth rates were reached at food concentrations ranging from 2.5 to 1.4 g C/ml depending on larval size, energetic carbon requirements of 0.09 to 3.15 g C l/d, respectively.

Borja *et al.* (2000) and Gittenberger & Van Loon (2011) both assigned *Polydora ciliata* to their AMBI Ecological Group IV 'second-order opportunistic species (slight to pronounced unbalanced situations)', and *Corophium volutator* to Group III 'Species tolerant to excess organic matter enrichment; these species may occur under normal conditions, but their populations are stimulated by organic enrichment (slight unbalance situations)'.

Sensitivity assessment: Records indicate the biotope occurs in areas with high detrital content (Connor *et al.*, 2004). Furthermore, the evidence presented suggests that the characterizing species of this biotope are likely to be stimulated by organic enrichment, and only affected by excessive organic enrichment (above the benchmark level). Resistance and resilience are therefore assessed as **High**, and the biotope considered **Not Sensitive** to organic enrichment involving deposition of 100 $gC/m^2/yr$.

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

SS.SMu.SMuVS.PolCvol is characterized by the very fine firm mud or clay substratum which supports the characterizing species *Polydora ciliata* and *Corophium volutator*. These species have very specific preference of suitable substrata. A change to a rock or artificial substratum would result in the loss of these species, significantly altering the character of the biotope. The biotope would be lost and/or reclassified.

Sensitivity assessment: Resistance to the pressure is considered **None**, and resilience **Very Low** based on the loss of suitable substratum to support the community of the characterizing species of *Polydora ciliata* and *Corophium volutator*. Sensitivity has been assessed as **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 sediment type)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

The biotope occurs only in very fine mud or clay (Connor *et al*., 2004). A change in sediment type by one Folk class would result in an increase in the fraction of sand and gravel in the substratum. The characterizing species would no longer be supported and the biotope would be lost and/or reclassified.

Sensitivity assessment: Resistance to the pressure is considered **None**, and resilience **Very Low** based on the loss of suitable substratum to support the community of the characterizing species. Sensitivity has been assessed as **High**. Although no specific evidence is described, confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

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

Removal of the substratum to 30 cm would result in the loss of the mat of *Polydora ciliata* tubes and of *Corophium volutator* that borrows up to 5 cm deep (Meadows & Reid, 1966). Resistance to the pressure is considered **None**. Newell *et al.* (1998) indicate that local hydrodynamics (currents and wave action) and sediment characteristics (mobility and supply) strongly influence the recovery of soft sediment habitats. The biotope occurs in low energy environments, so resilience is therefore judged as **Medium**. Sensitivity has been assessed as **Medium**.

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

Attached epifauna, such as the characterizing *Polydora* community in this biotope, can be entangled and removed by abrasion. Veale *et al.* (2000) reported that the abundance, biomass and production of epifaunal assemblages decreased with increasing fishing effort. Resampling of grounds that were historically studied (from the 1930s) indicates that some upright species have increased in areas subject to scallop fishing (Bradshaw *et al*., 2002).

The burrowing life habits of *Corophium volutator* are likely to provide some protection from abrasion at the surface only. However, any abrasion or physical disturbance is likely to reduce the density of *Corophium volutator* by emigration and increased mortality. For example, the sediment turnover caused by cockles and lugworms disturbed the burrows of *Corophium volutator* and caused a significant negative effect on *Corophium volutator* density as a result of increased rate of swimming making the amphipod more vulnerable to predation (Flach & De Bruin, 1993, 1994).

Sensitivity assessment: Erect epifauna are directly exposed to this pressure which would displace, damage and remove individuals (Veale *et al*., 2000; Boulcott & Howell, 2011). As a soft bodied species, *Polydora ciliata* is likely to be crushed and killed by an abrasive force or physical blow. However, some individuals are likely to survive as individuals can withdraw into burrows. Additionally, although the burrowing life habits of *Corophium volutator* are likely to provide some protection from abrasion at the surface only, physical disturbance is likely to have adverse impacts on the community. Abrasion may also damage the substratum resulting in loss of habitat. Resistance to abrasion is considered **Low** and resilience of the biotope is considered as **High**. The biotope therefore judged to have **Low** sensitivity to abrasion or disturbance of the surface of the seabed.

Penetration or disturbance of the substratum subsurface	None	Medium	Medium
	Q: High A: High C: High	Q: High A: Medium C: High	Q: High A: Medium C: High

Activities that penetrate below the surface are likely to tear up and remove a significant proportion of the *Polydora* tubes. Additionally, *Corophium volutator* burrows to 5 cm deep and is also likely to be removed. However, in the Columbia river, no significant difference was found in *Corophium volutator* densities before and after dredging a channel and no difference between the dredged site and a control site (McCabe *et al*., 1998). Presumably, the dredging did cause mortality of *Corophium volutator* but recolonization was so rapid that no difference was found.

Sensitivity assessment: Biotope resistance is assessed as **None** and recovery is assessed as **Medium** given the dependency of recruitment from neighbouring areas. Sensitivity is therefore assessed as **Medium**.

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

In the Firth of Forth, *Polydora ciliata* formed extensive mats in areas that had an average of 68 mg/l suspended solids and a maximum of approximately 680 mg/l, indicating the species is able to tolerate different levels of suspended solids (Read *et al*., 1982; Read *et al*., 1983). Occasionally, in certain places siltation is speeded up when *Polydora ciliata* is present because the species actually produces a 'mud' as it perforates soft rock and chalk habitats and larvae settle preferentially on substrates covered with mud (Lagadeuc, 1991).

Suspended sediment and siltation of those particles is important for tube building in *Polydora ciliata* so a decrease may reduce tube building or the thickness of the mud surrounding the 'colonies'. Daro & Polk (1973) reported that the success of *Polydora* is directly related to the quantities of muds of any origin carried along by rivers or coastal currents.

Corophium volutator lives in areas with very high sediment loads and it might be postulated that an increase would not affect them.

An increase in turbidity, reducing light availability may reduce primary production by phytoplankton in the water column. Although productivity in SS.SMu.SMuVS.PolCvol is secondary, a reduction in primary production in the water column may result in reduced food supply to detritus feeding *Polydora ciliata* and suspension/deposit feeder *Corophium volutator*, which in turn may affect growth rates and fecundity.

Sensitivity assessment: An increase in suspended solids at the pressure benchmark level is unlikely to affect the characterizing species of this biotope. However, a decrease in suspended matter in the biotope could result in limitation of material for tube building activity of *Polydora ciliata* and also in the substrate no longer being suitable for colonization by new recruits. Resistance of the biotope is therefore considered to be **Low** (loss of 25-75%) and resilience is **High**, so the biotope is considered to have **Low** sensitivity to a change in suspended solids at the pressure benchmark level.

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

Adults of *Polydora ciliata* produce a 'mud' resulting from the perforation of soft rock substrata (Lagadeuc, 1991). A *Polydora* mud can be up to 50 cm thick, but the animals themselves occupy only the first few centimetres. They either elongate their tubes, or have left them to re-build close to the surface.

Munari & Mistri (2014) investigated the spatio-temporal variation pattern of a benthic community following deposition of dredged material, at a maximum thickness of 30–40 cm. *Polydora ciliata* was amongst the first colonizers of the newly deposited sediments. The authors suggested that it was possible that the individuals migrated vertically through the deep layer of dredged sand. This was based on the results of Roberts *et al.* (1998) who suggested 15 cm as the maximum depth of overburden through which benthic infauna can successfully migrate. After one year, no adverse impact of sand disposal on the benthic fauna was detected on the study site (Munari & Mistri, 2014).

Corophium volutator was categorized in AMBI sedimentation Group III – ‘species insensitive to higher amounts of sedimentation, but don’t easily recover from strong fluctuations in sedimentation’ (Gittenberger & Van Loon, 2011). Experimental fences placed on mudflats caused sedimentation rates of 2-2.5 cm/month and reduced *Corophium volutator* densities from approximately 1700 m^{-2} to approximately 400 m^{-2}. In areas without fences, *Corophium volutator* numbers increased from approximately 1700 per m^{2} to 3500 per m^{2} (Turk & Risk, 1981 cited in Neal & Avant, 2006).

Where a coarse/impermeable layer was added to the seabed the suitability of the habitat for *Corophium volutator* would be reduced if these could not reach the surface or maintain burrows. Furthermore, a deposition of fine sediment is likely to take several tidal cycles to clear in the low energetic conditions where this biotope occurs.

Sensitivity assessment: Based on the evidence presented, *Polydora ciliata* is probably likely to resist smothering by 5 cm of sediment. However, the same ‘light’ deposition of fine sediment is likely to cause some mortality of *Corophium volutator*. Resistance is therefore assessed as **Low** and resilience as **High** and the biotope is considered to have **Low** sensitivity to a ‘light’ deposition of up to 5 cm of fine material in a single discrete event.

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

Adults of *Polydora ciliata* produce a 'mud' resulting from the perforation of soft rock substrata (Lagadeuc, 1991). A *Polydora* mud can be up to 50 cm thick, but the animals themselves occupy only the first few centimetres. They either elongate their tubes, or have left them to re-build close to the surface.

Munari & Mistri (2014) investigated the spatio-temporal variation pattern of a benthic community following deposition of dredged material, at a maximum thickness of 30–40 cm. *Polydora ciliata* was amongst the first colonizers of the newly deposited sediments. The authors suggested that it was possible that the individuals migrated vertically through the deep layer of dredged sand. This was based on the results of Roberts *et al.* (1998) who suggested 15 cm as the maximum depth of overburden through which benthic infauna can successfully migrate. After one year, no adverse impact of sand disposal on the benthic fauna was detected on the study site (Munari & Mistri, 2014).

Corophium volutator was categorized in AMBI sedimentation Group III – 'species insensitive to higher amounts of sedimentation, but don't easily recover from strong fluctuations in sedimentation' (Gittenberger & Van Loon, 2011). Experimental fences placed on mudflats caused sedimentation rates of 2-2.5 cm/month and reduced *Corophium volutator* densities from approximately 1700 m^{-2} to approximately 400 m^{-2}. In areas without fences, *Corophium volutator* numbers increased from approximately 1700 per m^2 to 3500 per m^2 (Turk & Risk, 1981 cited in Neal & Avant, 2006). Where a coarse/impermeable layer was added to the seabed, the suitability of the habitat for *Corophium volutator* would be reduced if these could not reach the surface or maintain burrows. Furthermore, a deposition of fine sediment is likely to take several tidal cycles to clear in the low energetic conditions where this biotope occurs.

Sensitivity assessment: Based on the evidence presented, *Polydora ciliata* is probably likely to resist smothering by 30 cm of sediment. However, the same 'heavy' deposition of fine sediment is likely to result in mortality of *Corophium volutator*. Resistance is therefore assessed as **Low** and resilience as **High** and the biotope is considered to have **Low** sensitivity to a 'heavy' deposition of up to 30 cm of fine material in a single discrete event.

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

Corophium volutator is widely used in ecotoxicological studies and know to uptake nanoplastics, but toxicity at the current environmental relevant concentrations has yet to be confirmed (Booth *et al.*, 2015). However, *Corophium volutator* forms an important food source for several species of birds and mobile predators such as fish and crabs (Hughes, 1988; Jensen & Kristensen, 1990; Raffaelli *et al.*, 1991; Flach & De Bruin, 1994; Brown *et al.*, 1999), which is likely to result in transition of the particles up the marine food chain. Nevertheless, there was insufficient evidence on which to assess the sensitivity of this biotope to the introduction of litter.

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 is available on which to assess this pressure.

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

Polydora ciliata may respond to vibrations from predators or bait diggers by retracting their palps into their tubes. *Corophium volutator* is probably sensitive to surface vibrations but little is known about the effects of noise on invertebrates. However, the species are unlikely to be affected by noise pollution and so the biotope is assessed as **Not Sensitive**.

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

SS.SMu.SMuVS.PolCvol is a sublittoral biotope (Connor *et al.*, 2004) and therefore not directly dependent on sunlight. However, changes in light in the biotope are likely to affect predation rates and consequently densities of *Corophium volutator*.

Sensitivity assessment. Although *Polydora* spp. can perceive light, this pressure is not considered relevant. Although changes in light may alter predation rates on *Corophium volutator*, it is unlikely to be relevant for the overall composition of the biotope given the species is already likely to be adapted to sustain high levels of predation. The biotope is considered to have **High** resistance and, by default, **High** resilience and therefore is **Not Sensitive** to the introduction of light.

Barrier to species movement	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not Relevant to biotopes restricted to open waters.

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

Polydora ciliata exhibits shadow responses withdrawing its palps into its burrow, believed to be a defence against predation. However, since the withdrawal of the palps interrupts feeding and possibly respiration, the species also shows habituation of the response (Kinne, 1970).

Corophium volutator has limited visual acuity and since it spends most of its life in a burrow it is unlikely to be affected by visual disturbances.

Sensitivity assessment: Resistance and resilience are assessed as **High** and the biotope judged as **Not Sensitive** to visual disturbance.

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

The important characterizing species in the biotope are not cultivated or likely to be translocated. This pressure is therefore considered **Not Relevant**.

Introduction or spread of invasive non-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

There is no evidence on the presence of non-indigenous species or impacts of non-indigenous species relevant to this biotope. This pressure is therefore considered **Not Relevant**.

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

Introduced organisms (especially parasites or pathogens) are a potential threat in all coastal ecosystems. However, so far, no information was found on microbial pathogens affecting *Polydora ciliata*.

Corophium volutator is parasitized by several species of trematodes in Europe and North American (McCurdy et al., 2000a; McCurdy et al., 2000b; Mouritsen & Jensen, 1997, cited in Shim *et al*., 2013). Mass mortalities of *Corophium volutator* have been associated to infestation by trematodes in the Wadden Sea (Jensen & Mouritsen, 1992). Studies conducted in the Baltic Sea suggested that increased parasitism by trematode species has a detrimental effect on local amphipods (Meissner & Bick, 1999; Mouritsen & Jensen, 1997 cited in Shim *et al*., 2013).

Sensitivity assessment. Although there are no records of the biotope being affected by the introduction of microbial pathogens in the British Isles, there are reports of mass mortality of characterizing species *Corophium volutator* (Jensen & Mouritsen, 1992). The biotope is therefore at risk and is judged to have **Low** resistance to this pressure. Resilience is assessed as **High** and the biotope is classed as having **Low** sensitivity to the introduction of microbial pathogens.

Removal of target species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

SS.SMu.SMuVS.PolCvol is currently not targeted by commercial fisheries and hence not directly affected by this pressure. This pressure is therefore considered **Not Relevant**.

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

Direct, physical impacts are assessed through the abrasion and penetration of the seabed pressures, while this pressure considers the ecological or biological effects of by-catch. The characterizing species in this biotope are highly likely to be damaged or directly removed by static or mobile gears that are targeting other species (see abrasion and penetration pressures).

The extraction of cockles by sediment raking and mechanical disturbance and digging for lugworms for bait is likely to cause significant mortality of *Corophium volutator*. Bait digging was found to reduce *Corophium volutator* densities by 39%, juveniles were most affected suffering a 55% reduction in dug areas (Shepherd & Boates, 1999).

Sensitivity assessment: Loss of the characterizing species of this biotope is likely to occur as a result of unintentional removal. Removal of the characterizing species would result in the biotope being lost. Thus, the biotope is considered to have a resistance of **Low** to this pressure and to have **High** resilience, resulting in the sensitivity being judged as **Low**.

Bibliography

Almeda, R., Pedersen, T.M., Jakobsen, H.H., Alcaraz, M., Calbet, A. & Hansen, B.W., 2009. Feeding and growth kinetics of the planktotrophic larvae of the spionid polychaete *Polydora ciliata* (Johnston). *Journal of Experimental Marine Biology and Ecology*, **382** (1), 61-68.

Bat, L., Raffaelli, D. & Marr, I.L., 1998. The accumulation of copper, zinc and cadmium by the amphipod *Corophium volutator* (Pallas). *Journal of Experimental Marine Biology and Ecology*, **223**, 167-184.

Booth, A. M., Hansen, B.H., Frenzel, M., Johnsen, H. & Altin, D., 2015. Uptake and toxicity of methylmethacrylate-based nanoplastic particles in aquatic organisms. *Environmental Toxicology and Chemistry*, **9999**, 1–9.

Borja, A., Franco, J. & Perez, V., 2000. A marine biotic index to establish the ecological quality of soft-bottom benthos within European estuarine and coastal environments. *Marine Pollution Bulletin*, **40** (12), 1100-1114.

Boulcott, P. & Howell, T.R.W., 2011. The impact of scallop dredging on rocky-reef substrata. *Fisheries Research* (Amsterdam), **110** (3), 415-420.

Bradshaw, C., Veale, L.O., Hill, A.S. & Brand, A.R., 2002. The role of scallop-dredge disturbance in long-term changes in Irish Sea benthic communities: a re-analysis of an historical dataset. *Journal of Sea Research*, **47**, 161-184.

Brils, J.M., Huwer, S.L., Kater, B.J., Schout, P.G., Harmsen, J., Delvigne, G.A.L. & Scholten, M.C.T., 2002. Oil effect in freshly spiked marine sediment on *Vibrio fischeri*, *Corophium volutator*, and *Echinocardium caudatum*. *Environmental Toxicology and Chemistry*, **21**, 2242-2251.

Brown, R.J., Conradi, M. & Depledge, M.H., 1999. Long-term exposure to 4-nonylphenol affects sexual differentiation and growth of the amphipod *Corophium volutator* (Pallas, 1766). *Science of the Total Environment*, **233**, 77-88.

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.

Bryant, V., McLusky, D.S., Roddie, K. & Newbery, D.M., 1984. Effect of temperature and salinity on the toxicity of chromium to three estuarine invertebrates (*Corophium volutator*, *Macoma balthica*, *Nereis diversicolor*). *Marine Ecology Progress Series*, **20**, 137-149.

Bryant, V., Newbery, D.M., McLusky, D.S. & Campbell, R., 1985. Effect of temperature and salinity on the toxicity of arsenic to three estuarine invertebrates (*Corophium volutator*, *Macoma balthica*, *Tubifex costatus*). *Marine Ecology Progress Series*, **24**, 129-137.

Bryant, V., Newbery, D.M., McLusky, D.S. & Campbell, R., 1985a. Effect of temperature and salinity on the toxicity of nickel and zinc to two estuarine invertebrates (*Corophium volutator*, *Macoma balthica*). *Marine Ecology Progress Series*, **24**, 139-153.

Callier, M. D., McKindsey, C.W. & Desrosiers, G., 2007. Multi-scale spatial variations in benthic sediment geochemistry and macrofaunal communities under a suspended mussel culture. *Marine Ecology Progress Series*, **348,** 103-115.

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/

Como, S. & Magni, P., 2009. Temporal changes of a macrobenthic assemblage in harsh lagoon sediments. *Estuarine, Coastal and Shelf Science*, **83** (4), 638-646.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B., 2004. The Marine Habitat Classification for Britain and Ireland. Version 04.05. Joint Nature Conservation Committee, Peterborough. www.jncc.gov.uk/MarineHabitatClassification.

Conradi, M. & Depledge, M.H., 1999. Effects of zinc on the life-cycle, growth and reproduction of the marine amphipod *Corophium volutator*. *Marine Ecology Progress Series*, **176**, 131-138.

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.

Daro, M.H. & Polk, P., 1973. The autecology of *Polydora ciliata* along the Belgian coast. *Netherlands Journal of Sea Research*, **6**, 130-140.

Diaz-Castaneda, V., Richard, A. & Frontier, S., 1989. Preliminary results on colonization, recovery and succession in a polluted areas of the southern North Sea (Dunkerque's Harbour, France). *Scientia Marina*, **53**, 705-716.

Dorsett, D.A., 1961. The reproduction and maintenance of *Polydora ciliata* (Johnst.) at Whitstable. *Journal of the Marine Biological Association of the United Kingdom*, **41**, 383-396.

Drolet, D., Kennedy, K. & Barbeau, M.A., 2013. Winter population dynamics and survival strategies of the intertidal mudflat amphipod *Corophium volutator* (Pallas). *Journal of Experimental Marine Biology and Ecology***, 441,** 126-137.

Fish, J.D. & Fish, S., 1974. The breeding cycle and growth of *Hydrobia ulvae* in the Dovey estuary. *Journal of the Marine Biological Association of the United Kingdom*, **54**, 685-697.

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

Fish, J.D. & Mills, A., 1979. The reproductive biology of *Corophium volutator* and *C. arenarium* (Crustacea: Amphipoda). *Journal of the Marine Biological Association of the United Kingdom*, **59**, 355-368.

Flach, E.C. & De Bruin, W., 1993. Effects of *Arenicola marina* and *Cerastoderma edule* on distribution, abundance and population structure of *Corophium volutator* in Gullmarsfjorden western Sweden. *Sarsia*, **78**, 105-118.

Flach, E.C. & De Bruin, W., 1994. Does the activity of cockles, *Cerastoderma edule* (L.) and lugworms, *Arenicola marina* (L.), make *Corophium volutator* Pallas more vulnerable to epibenthic predators: a case of interaction modification? *Journal of Experimental Marine Biology and Ecology*, **182**, 265-285.

Forbes, M.R., Boates, S.J., McNeil, N.L. & Brison, A.E., 1996. Mate searching by males of the intertidal amphipod *Corophium volutator* (Pallas). *Canadian Journal of Zoology*, **74**, 1479-1484.

Ford, R.B. & Paterson, D.M., 2001. Behaviour of *Corophium volutator* in still versus flowing water. *Estuarine, Coastal and Shelf Science*, **52**, 357-362.

Gamenick, I., Jahn, A., Vopel, K. & Giere, O., 1996. Hypoxia and sulphide as structuring factors in a macrozoobenthic community on the Baltic Sea shore: Colonization studies and tolerance experiments. *Marine Ecology Progress Series*, **144**, 73-85.

Gameson, 1982. The quality of the Humber Estuary, 1961-1981, *Yorkshire Water Authority*.

Gerdol, V. & Hughes, R.G., 1993. Effect of the amphipod *Corophium volutator* on the colonisation of mud by the halophyte *Salicornia europea*. *Marine Ecology Progress Series*, **97**, 61-69.

Gittenberger, A. & Van Loon, W.M.G.M., 2011. Common Marine Macrozoobenthos Species in the Netherlands, their Characterisitics and Sensitivities to Environmental Pressures. GiMaRIS report no 2011.08. DOI: 10.13140/RG.2.1.3135.7521

Grassle, J.F. & Grassle, J.P., 1974. Opportunistic life histories and genetic systems in marine benthic polychaetes. *Journal of Marine Research*, **32**, 253-284.

Green, J., 1961. A biology of Crustacea. London: H.F. & G. Witherby Ltd. 180pp.

Green, N.W., 1983. Key colonisation strategies in a pollution-perturbed environment. In *Fluctuations and Succession in Marine Ecosystems: Proceedings of the 17th European Symposium on Marine Biology, Brest, France, 27 September - 1st October 1982. Oceanologica Acta*, 93-97.

Gudmundsson, H., 1985. Life history patterns of polychaete species of the family spionidae. *Journal of the Marine Biological Association of the United Kingdom*, **65**, 93-111.

Gulliksen, B., 1977. Studies from the U.W.L. "Helgoland" on the macrobenthic fauna of rocks and boulders in Lübeck Bay (western Baltic Sea). *Helgoländer wissenschaftliche Meeresunters*, **30**, 519-526.

Hansen, B. W., Stenalt, E., Petersen, J.K. & Ellegaard, C., 2002. Invertebrate re-colonisation in Mariager Fjord (Denmark) after severe hypoxia. I. Zooplankton and settlement. *Ophelia* **56** (3), 197-213.

Harms, J. & Anger, K., 1983. Seasonal, annual, and spatial variation in the development of hard bottom communities. *Helgoländer Meeresuntersuchungen*, **36**, 137-150.

Harris, G.J. & Morgan, E., 1984a. The effects of salinity changes on the endogenous circa-tidal rhythm of the amphipod *Corophium volutator* (Pallas). *Marine Behaviour and Physiology*, **10**, 199-217.

Harris, G.J. & Morgan, E., 1984b. The effects of ethanol, valinomycin and cycloheximide on the endogenous circa-tidal rhythm of the estuarine amphipod *Corophium volutator* (Pallas). *Marine Behaviour and Physiology*, **10**, 219-233.

Hayward, P.J. & Ryland, J.S. (ed.) 1995b. *Handbook of the marine fauna of North-West Europe.* Oxford: Oxford University Press.

Hiscock, K., Langmead, O., Warwick, R. & Smith, A., 2005a. Identification of seabed indicator species to support implementation of the EU Habitats and Water Framework Directives. *Report to the Joint Nature Conservation Committee and the Environment Agency* The Marine Biological Association, Plymouth, 77 pp.

Hoare, R. & Hiscock, K., 1974. An ecological survey of the rocky coast adjacent to the effluent of a bromine extraction plant. *Estuarine and Coastal Marine Science*, **2** (4), 329-348.

Holmström, W.F. & Morgan, E., 1983b. The effects of low temperature pulses in rephasing the endogenous activity rhythm of *Corophium volutator* (Pallas). *Journal of the Marine Biological Association of the United Kingdom*, **63**, 851-860.

Hughes, R.G., 1988. Dispersal by benthic invertebrates: the *in situ* swimming behaviour of the amphipod *Corophium volutator*. *Journal of the Marine Biological Association of the United Kingdom*, **68**, 565-579.

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

Jensen, K.T. & Kristensen, L.D., 1990. A field experiment on competition between *Corophium volutator* (Pallas) and *Corophium arenarium* Crawford (Crustacea: Amphipoda): effects on survival, reproduction and recruitment. *Journal of Experimental Marine Biology and Ecology*, **137**, 1-24.

Jensen, K.T. & Mouritsen K.N., 1992. Mass mortality in two common soft bottom invertebrates, *Hydrobia ulvae* and *Corophium volutator*, the possible role of trematodes. *Helgolander Meeresuntersuchungen*, **46**, 329-339.

Kinne, O. (ed.), 1970. *Marine Ecology: A Comprehensive Treatise on Life in Oceans and Coastal Waters. Vol. 1 Environmental Factors Part 1.* Chichester: John Wiley & Sons

Lagadeuc, Y., 1991. Mud substrate produced by *Polydora ciliata* (Johnston, 1828) (Polychaeta, Annelida) - origin and influence on fixation of larvae. *Cahiers de Biologie Marine*, **32**, 439-450.

Maurer, D., Keck, R.T., Tinsman, J.C. & Leathem, W.A., 1982. Vertical migration and mortality of benthos in dredged material: Part III—polychaeta. *Marine Environmental Research*, **6** (1), 49-68.

McCabe, G.T. Jr., Hinton, S.A. & Emmett, R.L., 1998. Benthic invertebrates and sediment characteristics in a shallow navigation channel of the lower Columbia River. *Northwest Science*, **72**, 116-126.

McCurdy, D.G., Boates, J.S. & Forbes, M.R., 2000. Reproductive synchrony in the intertidal amphipod *Corophium volutator*. *Oikos*, **88**, 301-308.

McLusky, D.S., 1967. Some effects of salinity on the survival, moulting, and growth of *Corophium volutator* (Amphipoda). *Journal of the Marine Biological Association of the United Kingdom*, **47**, 607-617.

McLusky, D.S., 1968. Some effects of salinity on the distribution and abundance of *Corophium volutator* in the Ythan estuary. *Journal of the Marine Biological Association of the United Kingdom*, **48**, 443-454.

McLusky, D.S., 1982. The impact of petrochemical effluent on the fauna of an intertidal estuarine mudflat. *Estuarine, Coastal and Shelf Science*, **14**, 489-499.

Meadows, P. & Reid, A. (1966). The behaviour of *Corophium volutator* (Crustacea: Amphipoda). *Journal of Zoology* **150**(4): 387-399

Meadows, P.S. & Ruagh, A.A., 1981. Temperature preferences and activity of *Corophium volutator* (Pallas) in a new choice apparatus. *Sarsia*, **66**, 67-72.

Miramand, P., Germain, P. & Camus, H., 1982. Uptake of americium and plutonium from contaminated sediments by three benthic species: *Arenicola marina, Corophium volutator* and *Scrobicularia plana*. *Marine Ecology Progress Series*, **7**, 59-65.

Mouritsen, K. N., Mouritsen, L.T. & Jensen, K.T., 1998. Change of topography and sediment characteristics on an intertidal mud-flat following mass-mortality of the amphipod Corophium volutator. *Journal of the Marine Biological Association of the United Kingdom*, **78** (4), 1167-1180.

Munari, C. & Mistri, M., 2014. Spatio-temporal pattern of community development in dredged material used for habitat enhancement: A study case in a brackish lagoon. *Marine Pollution Bulletin* **89** (1–2), 340-347.

Murina, V., 1997. Pelagic larvae of Black Sea Polychaeta. *Bulletin of Marine Science*, **60**, 427-432.

Mustaquim, J., 1986. Morphological variation in *Polydora ciliata* complex (Polychaeta, Annelida). *Zoological Journal of the Linnean Society*, **86**, 75-88.

Neal, K.J. & Avant, P. 2006. *Corophium volutator* A mud shrimp. 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. Available from: http://192.171.193.68/species/detail/1661

Newell, R., Seiderer, L. & Hitchcock, D., 1998. The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recovery of biological resources on the sea bed. *Oceanography and Marine Biology: An Annual Review*, **36**, 127-178.

Pardal, M.A., Marques, J.-C. & Bellan, G., 1993. Spatial distribution and seasonal variation of subtidal polychaete populations in the Mondego estuary (western Portugal). *Cahiers de Biologie Marine*, **34**, 497-512.

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.

Pedersen, T. M., Almeda, R., Fotel, F.L., Jakobsen, Hans H., Mariani, P. & Hansen, B.W., 2010. Larval growth in the dominant polychaete *Polydora ciliata* is food-limited in a eutrophic Danish estuary (Isefjord). *Marine Ecology Progress Series*, **407**, 99-110.

Raffaelli, D., Limia, J., Hull, S. & Pont, S., 1991. Interactions between the amphipod *Corophium volutator* and macroalgal mats on estuarine mudflats. *Journal of the Marine Biological Association of the United Kingdom*, **71**, 899-908.

Read, P.A., Anderson, K.J., Matthews, J.E., Watson, P.G., Halliday, M.C. & Shiells, G.M., 1982. Water quality in the Firth of Forth. *Marine Pollution Bulletin*, **13**, 421-425.

Read, P.A., Anderson, K.J., Matthews, J.E., Watson, P.G., Halliday, M.C. & Shiells, G.M., 1983. Effects of pollution on the benthos of the Firth of Forth. *Marine Pollution Bulletin*, **14**, 12-16.

Reish, D.J., 1979. Bristle Worms (Annelida: Polychaeta) In *Pollution Ecology of Estuarine Invertebrates*, (eds. Hart, C.W. & Fuller, S.L.H.), 78-118. Academic Press Inc, New York.

Roberts, R. D., Gregory, M.R. & Foster, B.A., 1998. Developing an efficient macrofauna monitoring index from an impact study—a dredge spoil example. *Marine Pollution Bulletin*, **36** (3), 231-235.

Roddie, B., Kedwards, T., Ashby-Crane, R. & Crane, M., 1994. The toxicity to *Corophium volutator* (Pallas) of beach sand contaminated by a spillage of crude oil. *Chemosphere*, **29** (4), 719-727.

Rosenberg, R., 1977. Benthic macrofaunal dynamics, production, and dispersion in an oxygen-deficient estuary of west Sweden. *Journal of Experimental Marine Biology and Ecology*, **26**, 107-33.

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.

Shepherd, P.C.F. & Boates, S.J., 1999. Effects of commercial baitworm harvest on semipalmated sandpipers and their prey in the Bay of Fundy hemispheric shorebird reserve. *Conservation Biology*, **13**, 347-356.

Shim, K.C., Koprivnikar, J. & Forbes, M.R., 2013. Variable effects of increased temperature on a trematode parasite and its intertidal hosts. *Journal of Experimental Marine Biology and Ecology*, **439**, 61-68.

Smyth, J.C., 1968. The fauna of a polluted site in the Firth of Forth. *Helgolander Wissenschaftliche Meeresuntersuchungen*, **17**, 216-233.

Sordino, P., Gambi, M.C. & Carrada, G.C., 1989. Spatio-temporal distribution of polychaetes in an Italian coastal lagoon (Lago

Fusaro, Naples). *Cahiers de Biologie Marine*, **30**, 375-391.

Sundborg, Å., 1956. The River Klarälven: a study of fluvial processes. *Geografiska Annaler*, **38** (2), 125-237.

Van Colen, C., Montserrat, F., Vincx, M., Herman, P.M.J., Ysebaert, T. & Degraer, S., 2010. Long-term divergent tidal flat benthic community recovery following hypoxia-induced mortality. *Marine Pollution Bulletin* **60** (2), 178-186.

Veale, L.O., Hill, A.S., Hawkins, S.J. & Brand, A.R., 2000. Effects of long term physical disturbance by scallop fishing on subtidal epifaunal assemblages and habitats. *Marine Biology*, **137**, 325-337.

Vorobyova, L., Bondarenko, O. & Izaak, O., 2008. Meiobenthic polychaetes in the northwestern Black Sea. *Oceanological and Hydrobiological Studies*, **37** (1), 43-55.

Wilson, W.H. & Parker, K., 1996. The life history of the amphipod, *Corophium volutator*: the effects of temperature and shorebird predation. *Journal of Experimental Marine Biology and Ecology*, **196**, 239-250.