Echinocardium cordatum and *Ensis* spp. in lower shore and shallow sublittoral slightly muddy fine sand

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

Eliane De-Bastos & Jacqueline Hill

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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/124]. All terms and the MarESA methodology are outlined on the website (https://www.marlin.ac.uk)

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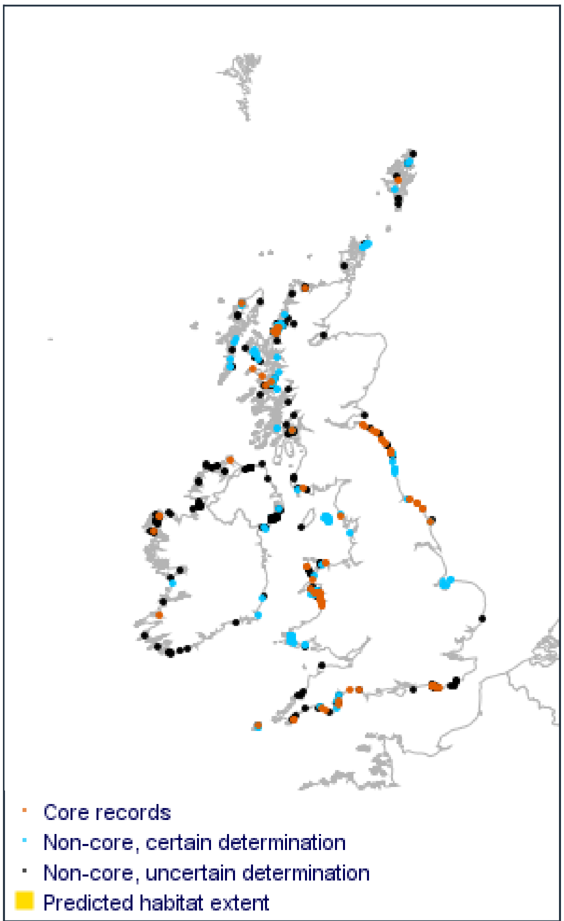
***Echinocardium cordatum* dug out of sand.**
Photographer: Anon.



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

Researched by Eliane De-Bastos & Jacqueline Hill **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A5.241	*Echinocardium cordatum* and *Ensis* spp. in lower shore and shallow sublittoral slightly muddy fine sand
JNCC 2015	SS.SSa.IMuSa.EcorEns	*Echinocardium cordatum* and *Ensis* spp. in lower shore and shallow sublittoral slightly muddy fine sand
JNCC 2004	SS.SSa.IMuSa.EcorEns	*Echinocardium cordatum* and *Ensis spp*. in lower shore and shallow sublittoral slightly muddy fine sand
1997 Biotope	SS.IMS.FaMS.EcorEns	*Echinocardium cordatum* and Ensis sp. in lower shore or shallow sublittoral muddy fine sand

Description

Sheltered lower shore and shallow sublittoral sediments of sand or muddy fine sand in fully marine conditions, supporting populations of the urchin *Echinocardium cordatum* and the razor shell *Ensis* *siliqua* or *Ensis ensis*. Other notable taxa within this biotope include occasional *Lanice conchilega*, *Pagurus* and *Liocarcinus* spp. and *Asterias rubens*. This biotope has primarily been recorded by epifaunal dive, video or trawl surveys where the presence of relatively conspicuous taxa such as *Echinocardium cordatum* and *Ensis* spp. have been recorded as characteristic of the community. However, these species, particularly *Echinocardium cordatum* have a wide distribution and are not necessarily the best choice for a characteristic taxa (Thorson, 1957). Furthermore, detailed quantitative infaunal data for this biotope is often rather scarce, possibly as a result of survey method as remote grab sampling is likely to under-estimate deep-burrowing species such as *Ensis* sp. (Warwick & Davis, 1977). Consequently, it may be better to treat this biotope as an epibiotic overlay which is likely to overlap a number of other biotopes such as FfabMag, NcirBat and AalbNuc with infaunal components of these biotopes occurring within EcorEns. The precise nature of this infaunal community will be related to the nature of the substratum, in particular the quantity of silt/clay present. Infaunal species may include the polychaetes *Spiophanes bombyx*, *Magelona mirabilis*, *Nephtys cirrosa* and *Chaetozone setosa* and the amphipod *Bathyporeia* spp. This biotope is currently broadly defined and needs further consideration as to whether it should be placed at biotope or biotope complex level. AreISa is another biotope based primarily on epibiotic data. It is likely that this biotope and EcorEns form a wider epibiotic sand /muddy sand community with EcorEns biased towards sandier areas and SSA.AreISa towards slightly muddier areas (this description was taken from Connor *et al*., 2004: JNCC).

Depth range

Lower shore, 5-10 m, 10-20 m, 20-30 m

Additional information

-

Listed By

- none -

Further information sources

Search on:

G G JNCC

Habitat review

Ecology

Ecological and functional relationships

- The characterizing and other species in this biotope occupy space in the habitat but their presence is most likely primarily determined by the occurrence of a suitable substratum rather by interspecific interactions.
- There are however, some interspecific relationships within the biotope. The bivalve *Tellimya (=Montacuta) ferruginosa* is a commensal of *Echinocardium cordatum*, and as many as 14 or more of this bivalve have been recorded with a single echinoderm. Adult specimens live freely in the burrow of *Echinocardium cordatum*, while the young are attached to the spines of the echinoderm by byssus threads (Fish & Fish, 1996). The amphipod crustacean *Urothöe marina* (Bate) is another common commensal (Hayward & Ryland, 1995).
- Predation in the biotope can be an important structuring force. Predators in the biotope include surface predators such as crabs, gastropods and fish; burrowing predators such as some polychaete worms and digging predators like *Cancer pagurus*. An increase in the numbers of these types of predators can have an influence on the abundance and diversity of species in benthic habitats (Ambrose, 1993; Wilson, 1991). For example, enclosure experiments in a sea loch in Ireland have shown that high densities of swimming crabs such as *Liocarcinus depurator*, that feed on benthic polychaetes, molluscs, ophiuroids and small crustaceans, led to a significant decline in infaunal organisms (Thrush, 1986).
- The hydrodynamic regime, which in turn controls sediment type, is the primary physical environmental factor structuring benthic communities such as IMS.EcorEns. The hydrography affects the water characteristics in terms of salinity, temperature and dissolved oxygen. It is also widely accepted that food availability (see Rosenberg, 1995) and disturbance, such as that created by storms, (see Hall, 1994) are also important factors determining the distribution of species in benthic habitats. The role of biological factors in the structuring of benthic communities is much more complicated than the physical and has proved to be much more difficult to assess experimentally.

Seasonal and longer term change

One of the key factors affecting benthic habitats is disturbance, which in shallow subtidal habitats will increase 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 (Rees *et al.*, 1976):

- Wave scour washed out some individuals of *Ensis ensis* although numbers were much lower than for some other fauna.
- The northerly gales threw piles of *Echinocardium cordatum* on to the strand line and the author suggests these events are not uncommon. Lawrence (1989) also reports that spatangoid echinoderms such as *Echinocardium cordatum* can be washed out by water currents generated by gales.
  Other organisms such as bivalves and brittle stars were also washed out of the sediment.

The numbers of many species in the biotope are likely to show peak abundances at certain times of the year due to seasonality of breeding and larval recruitment. Immature individuals of *Liocarcinus depurator*, for example, are more frequent in the periods May - September. Breeding of *Ensis ensis* probably occurs during spring and the veliger larvae has a pelagic life of about a month (Fish & Fish, 1996). *Echinocardium cordatum* is a long lived species and is unlikely to show significant seasonal changes.

Habitat structure and complexity

- The biotope has very little structural complexity with most species living in or on the sediment. Macroalgae are largely absent although in some areas sparse cover of seagrass may increase habitat heterogeneity because of the leaves and root rhizomes.
- Some structural complexity is provided by animal burrows although these are generally simple. The burrows of *Echinocardium cordatum*, for example, provide a habitat for other species such as the small bivalve *Tellimya (=Montacuta) ferruginosa*. Most species living within the sediment are limited to the area above the anoxic layer, the depth of which will vary depending on sediment particle size and organic content. However, the presence of burrows of species such as *Echinocardium cordatum* allows a larger surface area of sediment to become oxygenated, and thus enhances the survival of a considerable variety of small species (Pearson & Rosenberg, 1978).
- Deposit feeders manipulate, sort and process sediment particles and may result in destabilization and bioturbation of the sediment which inhibits survival of suspension feeders. Large deposit feeders like the lugworm *Arenicola marina* act like conveyor belts (Rhoads, 1974) ingesting particles from many centimetres below the surface, passing them through their guts and depositing them as faeces on the sediment surface. This often results in a change in the vertical distribution of particles in the sediment that may facilitate vertical stratification of some species with particle size preferences. Vertical stratification of species according to sediment particle size has been observed in some soft-sediment habitats (Peterson, 1977).

Productivity

Productivity in lower shore and shallow subtidal sediments is often quite low (Elliot *et al*., 1998). Macroalgae are generally absent and so productivity is mostly secondary, derived from detritus and organic material. 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 recycled. The high surface area of fine particles provides surface for microflora.

Recruitment processes

- In *Echinocardium cordatum* the sexes are separate and fertilization is external, with the development of a pelagic larva (Fish & Fish, 1996). The fact that *Echinocardium cordatum* is to be found associated with several different bottom communities would indicate that the larvae are not highly selective and discriminatory and it is probable that the degree of discrimination in 'larval choice' becomes diminished with the age of the larvae (Buchanan, 1966). Metamorphosis of larvae takes place within 39 days after fertilization (Kashenko, 1994). On the north-east coast of England a littoral population bred for the first time when three years old. In the warmer waters of the west of Scotland breeding has been recorded at the end of the second year (Fish & Fish, 1996). Buchanan (1967) observed that offshore populations were very slow growing and did not appear to reach sexual maturity so recruitment may be sporadic in places. However, since Buchanan (1967) also found that intertidal populations bred every year recruitment should take place on an annual basis.

- The razor shell *Ensis ensis* does not appear to breed before they are three years old. Breeding occurs during the summer but larval settlement is not successful every year, and recruitment of juveniles is irregular. Breeding probably occurs during spring and the veliger larvae has a pelagic life of about a month (Fish & Fish, 1996). Studies on razor shells from North Wales showed that individuals of *Ensis ensis* were mature in July but were spent in August, indicating that spawning had occurred by the middle of the summer (Henderson & Richardson, 1994).
- Most other macrofauna in the biotope breed several times in their life history (iteroparous) and are planktonic spawners producing large numbers of gametes (depending on food availability) with fertilisation in the water column. Dispersal potential is high, although in sheltered bays the larvae may be entrapped. Recruitment is linked to the hydrographic regime for dispersal and small scale eddy's (e.g. over obstacles and inconsistencies in the surface of the substratum) may result in concentration of larvae or propagules. High density of adults, suspension feeders and surface deposit feeders together with epibenthic predators and physical disturbance results in high post settlement mortality rate of larvae and juveniles (Olafsson *et al*., 1994). The larvae of some species may settle outside usual habitat preferences away from areas dominated by adults. Overall recruitment is likely to be patchy and sporadic, with high spat fall occurring in areas devoid of adults, perhaps lost due to predation or storms and habitats may alternate between being deposit feeder or suspension feeder dominated. Similarly larvae may be concentrated by the hydrographic regime or swept to neighbouring or removed sites.

Time for community to reach maturity

No evidence on community development was found. However, the two key species *Echinocardium cordatum* and *Ensis ensis* are long lived species and take a relatively long time to reach reproductive maturity. Razor shells, for example, do not appear to breed before they are three years old and UK populations of *Echinocardium cordatum* breed for the first time when two to three years old. Recruitment of *Echinocardium cordatum* is often sporadic with reports of recruiting in only 3 years over a 10 year period (Buchanan, 1966) although this relates to subtidal populations. Intertidal individuals reproduce more frequently. Many of the other species in the biotope, such as polychaetes and bivalves, are likely to reproduce annually. However, because the key species in the biotope, *Ensis ensis* and *Echinocardium cordatum*, are long lived and take several years to reach maturity the time for the overall community to reach maturity is also likely to be several years. Recovery of the benthos after mechanical harvesting in the tidal flats of the Wadden Sea, for example, took several years because of the slow re-establishment of a population of another large, long-lived invertebrate *Mya arenaria* (Beukema, 1995).

Additional information

No text entered.

Preferences & Distribution

Habitat preferences

Depth Range	Lower shore, 5-10 m, 10-20 m, 20-30 m
Water clarity preferences	
Limiting Nutrients	
Salinity preferences	Full (30-40 psu)
Physiographic preferences	
Biological zone preferences	Infralittoral
Substratum/habitat preferences	Muddy sand
Tidal strength preferences	Moderately Strong 1 to 3 knots (0.5-1.5 m/sec.), Very Weak (negligible), Weak < 1 knot (<0.5 m/sec.)
Wave exposure preferences	Exposed, Moderately exposed, Sheltered
Other preferences	No information found

Additional Information

Species composition

Species found especially in this biotope

Rare or scarce species associated with this biotope

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Additional information

No text entered.

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

SS.SSa.IMuSa.EcorEns occurs mainly in sheltered, exposed and moderately exposed lower shore and shallow sublittoral sediments of sand or muddy fine sand in fully marine conditions. The biotope supports populations of the urchin *Echinocardium cordatum* and the razor shell *Ensis siliqua* or *Ensis ensis*, but also other notable taxa including sand mason worm *Lanice conchilega*, and mobile taxa like hermit crab *Pagurus bernhardus*, harbour crab *Liocarcinus depurator* and starfish *Asterias rubens*. Survey methods to date have mainly focused on epibenthic fauna, resulting in a broad classification of the biotope, which is likely to overlap a number of other biotopes such as FfabMag, NcirBat, AalbNuc and AreISa, with infaunal components of these biotopes occurring within EcorEns. The infaunal community is likely to be diverse and may include the polychaetes *Spiophanes bombyx*, *Magelona mirabilis*, *Nephtys cirrosa* and *Chaetozone setosa* and the amphipod *Bathyporeia* spp. This diversity is likely to depend on the nature of the substrate, in particular the quantity of silt/clay. Seagrass *Zostera marina* may also occur in low densities, but density below that of Zmar. The heart urchin *Echinocardium cordatum* and the razor shells, represented by *Ensis ensis*, occur in high frequency and are the key species after which the biotope is named. *Ensis ensis* also serves to represent the functional group of suspension feeding burrowing bivalves in the biotope. Although mobile and able to move between habitats the swimming crab *Liocarcinus depurator* is often found in this biotope and is a predator of many of the benthic species present, and is here considered a key functional species of this biotope. *Echinocardium cordatum* and *Ensis ensis* are therefore considered the key characterizing species of SS.SSa.IMuSa.EcorEns, and the sensitivity assessments focus on these two species.

There are some interspecific relationships within this biotope. The bivalve *Tellimya (syn. Montacuta) ferruginosa* and amphipod crustacean *Urothöe marina (Bate)* are commensal of *Echinocardium cordatum* (Fish & Fish, 1996; Hayward & Ryland, 1995b). Predation is also a structuring factor in this biotope, with predator species present such as crabs, gastropods and fish influencing the abundance and variety of both epifaunal and infaunal communities.

Resilience and recovery rates of habitat

Echinocardium cordatum has high fecundity, reproduces every year and has high dispersal potential (Hill, 2008). *Echinocardium cordatum* is a long-lived species, growing on average up to 6 cm in length, and takes a relatively long time to reach reproductive maturity (Fish & Fish, 1996). Observation of populations over a period of seven years suggested the species has a lifespan greater than 10 years (Buchanan, 1966; Hayward *et al.*, 1996). However, in the Mediterranean, Guillou (1985) suggested a lifespan of one or two years. Recruitment of subtidal populations of *Echinocardium cordatum* is often sporadic with reports of recruitment in only three years over a 10 year period (Buchanan, 1966), with intertidal individuals reproducing more frequently. UK populations of *Echinocardium cordatum* breed for the first time when two to three years old, and in the west coast of Scotland breeding has been recorded at the end of the second year (Fish & Fish, 1996). Buchanan, (1967) observed that subtidal populations appear never to reach sexual maturity and that offshore populations were very slow growing. However, since Buchanan (1967) also found that intertidal populations bred every year, recruitment could take place on an annual basis. In *Echinocardium cordatum* the sexes are separate and fertilization is external, with the development of a pelagic larva (Fish & Fish, 1996). The fact that *Echinocardium cordatum* is to be found associated with several different bottom communities would indicate that the larvae are not highly selective and discriminatory (Buchanan, 1966). This agrees with the results of Nunes &

Jangoux (2008) who suggested that neither the competent larvae nor the juveniles appear to be very specific in terms of sediment type, suggesting that other factors (e.g. mortality or migration) would determine the distribution and abundance of adult populations. Growth in *Echinocardium cordatum* is particularly rapid during the first and second years of life and there are also seasonal variations that are characterized by an alternation of slow and rapid growth rates, with rapid growth during spring and summer months (Ridder de *et al*., 1991).

Ensis ensis is also a long-lived species, growing up to 13 cm in length. It also takes a relatively long time to reach reproductive maturity, not appearing to breed before they are three years old (Henderson & Richardson, 1994). Breeding occurs during the summer but larval settlement is not successful every year, and recruitment of juveniles is irregular. Breeding probably occurs during spring and the veliger larvae has a pelagic life of about a month (Fish & Fish, 1996). Studies on razor shells from North Wales showed that individuals of *Ensis ensis* were mature in July but were spent in August, indicating that spawning occurred by the middle of the summer (Henderson & Richardson, 1994). Populations may be skewed towards smaller and younger individuals. However, all invertebrate communities respond to perturbations in a similar way. Initial massive mortality and lowered community diversity is followed by extreme fluctuations in populations of opportunistic mobile and sessile fauna (Suchanek, 1993). Oscillations in population numbers slowly dampen over time and diversity slowly increases to original levels.

Most other macrofauna in the biotope breed several times in their life history (iteroparous) and are planktonic spawners producing large numbers of gametes (depending on food availability) with fertilization in the water column. Dispersal potential is high, although in sheltered bays the larvae may be entrapped. Recruitment is linked to the hydrographic regime for dispersal and small scale eddy's (e.g. over obstacles and inconsistencies in the surface of the substratum) may result in concentration of larvae or propagules. High density of adults, suspension feeders and surface deposit feeders together with epibenthic predators and physical disturbance results in high post settlement mortality rate of larvae and juveniles (Olafsson *et al*., 1994). The larvae of some species may settle outside usual habitat preferences away from areas dominated by adults. Overall recruitment is likely to be patchy and sporadic, with high spat fall occurring in areas devoid of adults, perhaps lost due to predation or storms, and habitats may alternate between being deposit feeder or suspension feeder dominated. Similarly, larvae may be concentrated by the hydrographic regime or swept to neighbouring or removed sites.

Resilience assessment: Because the key species in the biotope, *Ensis ensis* and *Echinocardium cordatum*, are long lived and take several years to reach maturity the time for the overall community to reach maturity is also likely to be several years. *Echinocardium cordatum* re-populated sediments two years after *Torrey Canyon* oil spill, and the razor shell *Ensis* was reported to be slower to return after mass mortality caused by the disaster (Southward & Southward, 1978). Also recruitment of subtidal populations of *Echinocardium cordatum* is often sporadic with reports of recruitment in only 3 years over a 10 year period (Buchanan, 1966).

Therefore, where the biotope has **Medium** resistance to a disturbance, resilience is likely to be **High** or given that the majority of the key species of the biotope can maintain the character to the biotope and recruit within the first two years after disturbance. However, when a significant proportion of the population is lost (resistance **Low** or **None**), although the individual key species may recolonize the area within five years, the biotope may take longer to return to original species diversity and abundance and resilience is likely to be **Medium** (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: Medium C: High	High Q: High A: High C: Medium	Not sensitive Q: Medium A: Medium C: Medium

Echinocardium cordatum is found from Norway to South Africa, Mediterranean, Australasia and Japan, and *Ensis ensis* is widely distributed in the north west of Europe. Both species are therefore likely to experience seasonal changes in water temperatures by as much as 10°C from summer to winter, although growth and fecundity could probably be affected. A study by Kashenko (2007) of the combined effects of temperature and salinity on the development of the sea urchin *Echinocardium cordatum*, in the Vostok Bay of the Sea of Japan suggested that fertilization and embryonic development were completed successfully at a range of temperatures (12-20 and 8-20°C, respectively). Results presented by Kirby *et al.* (2007), suggested that the increased abundance and spatial distribution in the North Sea of the larvae of *Echinocardium cordatum*, could have been caused by an increase in sea temperature after 1987 and that the key stages of reproduction, gametogenesis and spawning, appeared to be influenced by winter and spring sea temperature. These results suggest that *Echinocardium cordatum*'s recruitment may benefit from local increases in temperature. Populations of the razor shell *Ensis siliqua* in the warmer waters of Portugal spawn several months earlier in the year than UK populations and are sexually mature at only one year old (Gaspar & Monteiro, 1998; Henderson & Richardson, 1994) compared to three in the UK (Hill, 2006). Recruitment of *Ensis* spp. in this biotope is therefore likely to be affected by an increase in temperature. Some protection may be afforded by burrowing position.

Infaunal species are not subjected to the larger temperature variations experienced in the intertidal and so many of the other species in the biotope may be less resistant to changes, leading to a decline in species diversity. Temperature may also affect microbial activity within the sediment which could alter the depth at which the anoxic layer appears. There can be mass mortality of *Echinocardium cordatum* on sandy shores following oxygen depletion during extreme low water tides on hot days, as a result of high temperatures causing suffocation (D. Nichols pers. comm., cited in Hill, 2008).

Sensitivity assessment: The cosmopolitan distribution of the two species means they may be resistant to local increases in temperature at the pressure benchmark level. Resistance and resilience are, therefore, assessed as **High** and the group is considered **Not Sensitive** at the pressure benchmark level.

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

Echinocardium cordatum is found from Norway to South Africa, Mediterranean, Australasia and Japan, and *Ensis ensis* is widely distributed in the north west of Europe. Both species are therefore likely to experience seasonal changes in water temperatures by as much as 10°C from summer to winter. However, mortality of both species was observed in the very cold winter of 1962-63 (Crisp, 1964) and growth and fecundity could probably be affected. A study by Kashenko (2007) of the combined effects of temperature and salinity on the development of sea urchin *Echinocardium cordatum*, in Vostok Bay of the Sea of Japan, suggested that resistance of *Echinocardium cordatum* to fluctuations in temperature varied in the course of individual development, but fertilization and embryonic development were completed successfully at a range of temperatures (12-20 and 8-20°C, respectively). However, embryonic development did not occur as fast at lower temperatures. Additionally, changes in temperature may have cascading effects on the entire food web, potentially affecting all stages of benthic organisms (Schückel *et al.*, 2010, cited in Kröncke *et al.*, 2013a). Kröncke *et al.* (2013a) reported mortality of macrofauna species during and after the cold winters of 1978/1979 and 1995/96 that affected species biomass and abundance in the study area (the southern North Sea), including of the characterizing and other species of this biotope. Although the effects of the 1995/96 winter on macrofauna diversity was considered minor compared with 78/79, as the later was followed by three cold winters in the early 80's, the cold winters seemed to have caused biological regime shifts in the years following the cold events. For example, the proportion of northern species increased and opportunistic species that feed on organic detritus thrived from feeding on decaying benthic organisms (Kröncke *et al.*, 2013a).

Temperature may also affect microbial activity within the sediment which could alter the depth at which the anoxic layer appears.

Sensitivity assessment: The characterizing species of this biotope have a cosmopolitan distribution, and Kashenko (2007) suggested some plasticity in recruitment of *Echinocardium cordatum* to varying temperature parameters. However, individual adults of the key characterizing species may be adversely affected by decreases in temperature as suggested by Kröncke *et al.* (2013a), who reported mortality of the key characterizing species at -2°C anomalies in sea-surface temperature. Resistance is therefore assessed as **Medium** and resilience assessed as **High** and the biotope is considered to have **Low** sensitivity to this pressure at the benchmark level.

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

The biotope is only recorded in fully marine conditions so is unlikely to be resistant to changes in salinity. Echinoderms, such as *Echinocardium cordatum*, are stenohaline species owing to the lack of an excretory organ and a poor ability to osmo- and ion-regulate (Stickle & Diehl, 1987; Russell, 2013). A review by Russell (2013) on echinoderms responses to variable salinities did not report observations of *Echinocardium cordatum* in hypersaline conditions, hence this species is unlikely to be able to resist wide fluctuations in salinity. Salting is often used as a method of dislodging razor shells from their burrows, suggesting that *Ensis* spp. are unlikely to resist hypersaline conditions.

Sensitivity assessment: No direct evidence was found on the resistance of the characterizing species of the biotope to increased salinity. Long-term changes in salinity are likely to result in the loss of some species, and also result in decrease of species richness. Resistance of the biotope is assessed as **Low** and resilience as **Medium**, but with low confidence. The biotope is therefore considered to have **Medium** sensitivity to increases in salinity at the pressure benchmark level.

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

The biotope is found in fully marine conditions so is unlikely to be resistant to changes in salinity. Echinoderms, such as *Echinocardium cordatum*, are stenohaline species owing to the lack of an excretory organ and a poor ability to osmo- and ion-regulate (Stickle & Diehl, 1987; Russell, 2013). Although Wolff (1968) reported populations of *Echinocardium cordatum* occuring at 27‰ in The Netherlands, studies by Kashenko (2006, 2007) suggested that the species is unable to resist fluctuations in salinity. Embryos seemed to only tolerate a narrow range of salinity between 36‰ and 28‰ (Kashenko, 2007), while adults were reported to only tolerate a salinity range between 33 and 28‰ (Kashenko, 2006).

Ensis ensis does not occur in water of reduced salinity, although its absence from estuaries may sometimes be due to the lack of sediments of suitable grade (Holme, 1954). The species concentrates K and Ca (Kinne, 1971b) and may be able to resist a degree of salinity reduction because it will be subject to periodic precipitation in the intertidal. Darriba & Miranda (2005) concluded that salinity decreases interrupted gonadal development in the razor clam *Ensis magnus*.

Sensitivity assessment: Long-term changes in salinity are likely to result in the loss of the characterizing species of this biotope. The evidence suggests that *Echinocardium cordatum* is unlikely to survive reduced salinities (18-30‰) for a year and *Ensis* spp. may suffer reproductive disruption. Resistance of the biotope is therefore assessed as **None** and resilience as **Medium**. The biotope is therefore considered to have **Medium** sensitivity to decreases in salinity at the pressure benchmark level.

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

Changes in the water flow rate are likely to change the sediment structure and have concomitant effects on the community. The biotope is found in sediments of medium to fine sand or muddy fine sand in moderate to very weak tidal steams (Connor *et al.*, 2004). An increase in water flow rate may remove smaller sediment particles leaving coarser elements behind which may be unsuitable for some of the burrowing fauna in the biotope. Individuals of *Echinocardium cordatum* and *Ensis ensis* are often washed out by increased water flow (Lawrence, 1996; Henderson & Richardson, 1994). A decrease in species diversity is likely to be observed, with the loss of the two key species and the loss of other small invertebrates such as bivalves that inhabit the burrows of *Echinocardium cordatum*. However, since *Ensis ensis* is able to burrow deeper into the sediment during unsuitable conditions, water flow rates would have to increase substantially to remove individuals.

A decrease in water flow could likely favour muddy sediments, which could result in change of species composition and loss of *Ensis* spp. and *Echinocardium cordatum* in favour of more muddy species, which would result in reclassification of the biotope to AreISa (Connor *et al.*, 2004).

Sensitivity assessment: The assessment is based largely on the Hjulström-Sundborg diagram (Sundborg, 1956). This relates current velocity to deposition, erosion and transport. While this model has largely been superseded in by more recent models that take into account other factors such as shear stress and water depth, these newer models are more complex, site specific and do not relate sediment transport to water velocity. The curve is therefore used to assess generally the potential effects of changes in water velocity but it should be recognized that a number of other factors will mediate effects. The biotope is found in sediments of medium to fine sand or muddy fine sand in moderate to very weak tidal steams (Connor *et al.*, 2004). A change in water flow could potentially change the sediment type. However, a change at the benchmark level of 0.1-0.2 m/s is likely to fall within the range experienced by the biotope. Resistance and resilience are therefore considered to be **High** and the biotope is assessed as **Not Sensitive** to a change in water flow rate at the pressure benchmark level.

Emergence regime changes	High Q: Low A: Low C: Low	High Q: High A: High C: Medium	Not sensitive Q: Low A: Low C: Low

The biotope extends from the very low shore to the shallow subtidal so an increase in emergence is likely to affect only the upper range of the biotope. Species like *Ensis ensis* and *Echinocardium cordatum* have little protection from desiccation when exposed and are likely to be lost if the length of time of exposure increases. Other species like crabs and errant polychaetes are likely to be able to migrate to unaffected areas. An increase in desiccation may cause some individuals to be lost at the extreme upper limit of the biotope although most species are able to re-burrow if exposed to air. However, Sievers *et al.* (2014) observed predation behaviour of carrion crows (*Corvus corone*) feeding on spatangoid sea urchins (*Echinocardium cordatum*) during low tide on two different beaches in Brittany, France, and suggested that sea urchin size and predation pressure could be linked. Thus, changes in emergence regime are likely to change exposure to predation by birds, with potential impacts on the biotope's biological community. A decrease in emergence may enable the biotope to extend its range up-shore.

Sensitivity assessment: Although a change in emergence regime may affect the biological community on the upper range of the biotope, the sublittoral element of the biotope is not likely to be lost and the overall species richness of the biotope is not likely to change. A change in emergence regime experienced by mid-range populations are unlikely to be affected, so resistance and resilience are considered to be **High** and the biotope is assessed as **Not Sensitive** at the pressure benchmark level.

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

One of the key factors affecting benthic habitats is disturbance, which in shallow subtidal habitats will increase in winter due to weather conditions. Storms may cause dramatic changes in distribution of benthic communities by reducing success of recruitment by newly settled spat or larvae (Hall, 1994). The biotope is found in wave exposed, moderately wave exposed and sheltered areas (Connor *et al.*, 2004). According to the wave exclusion hypothesis proposed by Paavo *et al.* (2011, cited in Armonies *et al.*, 2014), the community of benthic organism found in the surf zone is not excluded by wave action. The depth at which this biotope occurs (from lower shore up to 20 m) suggests that the biological community present would not be excluded by wave action and is therefore likely to be able to resist disturbance. An increase in wave exposure is likely to disturb the fine sediment that characterizes this biotope, and may even displace some species as to change the composition of species present in the biotope. However, *Echinocardium cordatum* has been recorded from a range of wave exposure conditions, including extremely sheltered, very sheltered, sheltered, moderately exposed, exposed, very exposed (Tillin & Tyler-Walters, 2014). Furthermore, Wolff (1968) and Guillou (1985) have reported the species in coastal waters of The Netherlands in the tidal zone on some sandflats exposed to wave-action, and in the bay of Douarnenez, Brittany in areas of fine sand dominated by high sediment instability, respectively. On the other hand, razor shells seem to be absent on exposed beaches where the sand is continually churned by waves and Rees *et al.* (1976) reported that wave scour caused by winter gales may have caused some individuals of *Ensis ensis* to be washed out along the north Wales coast. Therefore, an increase in wave exposure may remove some individuals of *Ensis ensis* in a population.

Sensitivity assessment: An increase in wave action is likely to increase the coarseness of the sediment. If muddy sands were replaced by medium to fine sand, then the biotope would probably survive although the infaunal community would change. However, an increase in storminess could result in loss of areas of sand and hence the biotope. Conversely a reduction in wave action, may result in muddy sediments, depending on water flow conditions, and loss of the biotope. However, the biotope is found in wave exposed, moderately wave exposed and sheltered areas (Connor *et al.*, 2004) and change at the pressure benchmark level is likely to fall within the range experienced by the biotope. Resistance is therefore considered to be **High** and resilience is considered to be **High** (by default) and the biotope judged **Not Sensitive** to a change in nearshore significant wave height >3% but <5%.

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.

No details about the effects of heavy metals specific to *Echinocardium cordatum* and razor shells were found, and different members of the same community are likely to vary in their resistance. Bryan (1984) suggested that metal-contaminated sediments can exert a toxic effect on burrowing bivalves and echinoderms, especially at larval stages, and that polychaetes were fairly resistant. Possible suggested effects of this toxicity were reduced growth, abundance and abnormalities in areas of heavy pollution. Kanakaraju *et al.* (2008) found that, of the heavy metal contents analysed (Pb, Fe, Zn, Cu, Cd and Mn) razor clams of the *Solen* spp. in Malasya concentrated higher levels of Fe and Zn in their tissues, and Pb and Mn in their shells. These results suggest that razor clams potentially are likely to bio-accumulate toxic heavy-metals from their environment, but no biological effects of this bio-accumulation were suggested.

The evidence suggests that the characterizing species of this biotope are likely to bio-accumulate toxic heavy metals and that this accumulation may affect the biotope by limiting populations growth, abundance and recruitment.

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.

Oil spills resulting from tanker accidents can cause large-scale deterioration of communities in intertidal and shallow subtidal sedimentary systems. The two key species in the biotope, *Echinocardium cordatum* and *Ensis ensis* suffered mass mortality after the *Torrey Canyon* and *Amoco*

Cadiz oil spills (Southward & Southward, 1978; Southward, 1978; Cabioch *et al.*, 1978), which suggests low resistance oil pollution. Many other species in the biotope are also likely to be affected. For example, after the West Falmouth, *Florida* spill of 1969 the entire benthic fauna was eradicated immediately following the spill and populations of the opportunistic polychaete *Capitella capitata* increased to abundances of over 200,000/m (Sanders, 1978). *Ensis ensis* is reported to bio-concentrate aromatics and is highly likely to be sensitive to hydrocarbons. Four days after the *Sea Empress* oil spill moribund razor shells (mostly *Ensis siliqua*) were the first organisms observed to have been affected (SEEEC, 1998). Glegg & Rowland (1996) observed dead razor shells washed up on the shore a few days after the final break-up of the *Braer* wreck. Echinoderms have not been found to be resistant to the toxic effects of oil, likely because of the large amount of exposed epidermis (Suchanek, 1993). Reduced abundance of *Echinocardium cordatum* was also detectable up to > 1000 m away one year after the discharge of oil-contaminated drill cuttings in the North Sea (Daan & Mulder, 1996). However, invertebrate communities respond to severe chronic oil pollution in much the same way. Initial massive mortality and lowered community diversity is followed by extreme fluctuations in populations of opportunistic mobile and sessile fauna (Suchanek, 1993). Oscillations in population numbers slowly dampen over time and diversity slowly increases to original levels. Infaunal communities, such as those characterizing this biotope are highly likely to be adversely affected by an event of oil pollution, but the biological effects of accumulation of PAHs are likely to depend on the length of time exposed (Viñas *et al.*, 2008).

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.

High levels of mortality of both *Echinocardium cordatum* and *Ensis* spp. resulted from the use of dispersants following the *Torrey Canyon* oil spill (Smith, 1968). Almost complete mortality of razor shells was found at stations more than a kilometre from the shore at a depth of about 20 m. The toxicity of TBT to *Echinocardium cordatum* is similar to that of other benthic organisms and echinoderms do not tend to be resistant of various types of marine pollution (Newton & McKenzie, 1995). Sea urchins, especially the eggs and larvae, are used for toxicity testing and environmental monitoring (reviewed by Dinnel *et al.*, 1988). It is likely therefore, that *Echinocardium cordatum* and especially its larvae are highly sensitive to synthetic contaminants. Other species in the biotope, in particular polychaete worms, are generally more resistant of a range of marine pollutants so a change in the faunal composition may be expected if chemical pollution increases. Polluted areas would be characterized by biotopes with lower species diversity and a higher abundance and density of pollution resistant species such as polychaetes.

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

Monitoring studies by Sohtome *et al.* (2014) of radioactive concentration in invertebrates of the benthic food web community within the Fukushima area confirm that echinoderm *Echinocadium cordatum* is likely to uptake contaminated sediments into their digestive tract. Carvalho (2011) determined the concentrations of ^{210}Po and ^{210}Pb in marine organisms from the seashore to abyssal depths, as these two radioactive elements tends to be higher in the marine environment. The author's results showed that concentrations varied greatly, even between organisms of the same biota, mainly related with the trophic levels occupied by the species, suggesting that the more levels between a species and the bottom of the food chain, the more likely that the concentrations of radioactive elements were likely to be diluted. This may have great implications for the detritus and filter feeders that characterize this biotope. There was no information available about the effect of this bioaccumulation.

Sensitivity assessment: Although species in this biotope are likely to bio-accumulate radionuclides with potential impacts on the biological community, no information concerning the effects of such bioaccumulation was found. Therefore, there is insufficient evidence to assess this pressure against the benchmark.

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: High C: High	Medium Q: High A: High C: High	Medium Q: High A: High C: High

Oxygen-deficient marine areas are characterized by a decline in the number and diversity of species. A decrease in oxygenation is likely to see the loss of the key species in the biotope. For example, in the south-eastern North Sea, a period of reduced oxygen resulted in the death of many individuals of *Echinocardium cordatum* (Niermann, 1997) and during periods of hypoxia the species migrates to the surface of the sediment (Diaz & Rosenberg, 1995). Low resistance of *Echinocardium cordatum* has also been demonstrated in laboratory experiments. Over a 21 day-long experiment, individuals appeared on the sediment surface at 4 mg/l and many were dead at a concentration of 2.4 mg/l (Nilsson & Rosenberg, 1994). *Ensis ensis* is likely to be more resistant than *Echinocardium cordatum*, and tolerate sands that are slightly reducing, in which there is a grey layer below the surface, but is likely to eventually die in low oxygenated areas (Holme, 1954).

Sensitivity assessment: A decrease in oxygenation at the pressure benchmark level is likely to result in significant (25-75%) mortality of the characterizing species of this biotope. With the loss of these species, the biotope would likely be lost. Community composition would likely become dominated by fewer species that are resistant of hypoxic conditions, such as some polychaete worms, so that the overall species richness would decline significantly. Resistance is therefore assessed as **Low** and resilience as **Medium**, and the biotope is judged as having **Medium** sensitivity to de-oxygenation at the pressure benchmark level.

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

Increases in organic content can result in significant change in the community composition of sedimentary habitats. An increasing level of nutrients in the sediment is likely to result in a reduction in the abundance of the key species, in particular the heart urchin *Echinocardium cordatum*, which is generally associated with sediments of low organic content (Buchanan, 1966). Pearson & Rosenberg (1976) described the changes in fauna along a gradient of increasing organic enrichment by pulp fibre. *Echinocardium cordatum* was absent from all but distant sediments with low organic input (Pearson & Rosenberg, 1976). Growth levels of this species have been observed to be lower in sediments with high organic content although it is suggested that this may be due to higher levels of intra-specific competition (Duineveld & Jenness, 1984). *Echinocardium cordatum* was also absent from an area in the southern North Sea into which large quantities of sewage sludge from Hamburg had been dumped and the species was never seen to settle in the area (Caspers, 1980). Townsend (2007) investigated the relationship between biodiversity, ecosystem functioning and nutrient cycling (nitrite, nitrate, ammonium, silicate and phosphate fluxes) in subtidal marine benthic ecosystems, using mesocosm systems. The author found that species responded to changing sediment conditions and to the presence of other species. *Echinocardium cordatum* performed differently according to sediment types, and was found to over yield (i.e. a more efficient use of available resources due to their complementarity or facilitation) when found in benthic assemblages with *Amphiura filiformis* and *Nereis virens*, which consequently increased nutrient exchange (Townsend, 2007). Although no specific information regarding the response of *Ensis ensis* to changes in nutrient levels was found, as filter-feeders, *Ensis* spp. are likely to benefit from some nutrient enrichment.

Sensitivity assessment: The overall species diversity in this biotope is likely to decline and the habitat becomes modified as numbers of bioturbating species decline. The community, and hence the biotope, may change to one dominated by nutrient enrichment resistant species, in particular polychaete worms such as *Capitella capitata*. However, these changes generally refer to gross nutrient enrichment. A decrease in nutrient availability may result in impaired growth and fecundity although species diversity is not likely to be affected significantly. Nevertheless, the biotope is considered to be **Not Sensitive** at the pressure benchmark that assumes compliance with good status as defined by the WFD.

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

Typically, an increasing gradient of organic enrichment results in a decline in the suspension feeding fauna and an increase in the number of deposit feeders, in particular polychaete worms (Pearson & Rosenberg, 1978), which could result in significant change in the community composition of sedimentary habitats. An increasing level of nutrients in the sediment is likely to result in a reduction in the abundance of the key species, in particular the heart urchin *Echinocardium cordatum*, which is generally associated with sediments of low organic content (Buchanan, 1966). Pearson & Rosenberg (1976) described the changes in fauna along a gradient of increasing organic enrichment by pulp fibre. *Echinocardium cordatum* was absent from all but distant sediments with low organic input (Pearson & Rosenberg, 1976). Growth levels of this species have been observed to be lower in sediments with high organic content although it is suggested that this may be due to higher levels of intra-specific competition (Duineveld & Jenness, 1984). *Echinocardium cordatum* was also absent from an area in the southern North Sea into which large quantities of sewage sludge from Hamburg had been dumped and the species was never seen to settle in the area (Caspers, 1980). Although no specific information regarding the response of *Ensis ensis* to changes in organic content was found, as filter-feeders, *Ensis* spp. are likely to benefit from some organic enrichment. Osinga *et al.* (1997) assessed the effects of sub-surface bacterial production on *Echinocardium cordatum* by adding up to 90 gC/m^2 in one event to sediment surfaces in experimental mesocosms. No detrimental effects on *Echinocardium cordatum* individuals were reported. Borja *et al.* (2000) and Gittenberger & van Loon (2011) in the development of the AZTI Marine Biotic Index (AMBI), a biotic index to assess disturbance (including organic enrichment), assigned *Echinocardium cordatum* and *Ensis* spp. to different Ecological Groups. Borja *et al.* (2000) considered that both species belonged to Ecological Group I 'species very sensitive to organic enrichment and present under unpolluted conditions'. However, Gittenberger & van Loon (2011) considered that both species belonged to Ecological Group II 'species indifferent to enrichment, always present in low densities with non-significant variations with time'. Although the unpublished Gittenberger & van Loon (2011) report is an update on Borja *et al.* (2000), the former is a peer reviewed publication.

Although no specific information regarding the response of *Ensis ensis* to changes in nutrient levels was found, as filter-feeders, *Ensis* spp. are likely to benefit from some organic enrichment.

Sensitivity assessment: The evidence presented based on the AMBI scores conflicts and is considered with caution. The biotope is generally found in areas with some water movement and this is likely to disperse organic matter reducing organic material load. However, the characterizing species of this biotope are likely to adversely suffer from an event of organic enrichment (Borja *et al.*, 2000) and resistance is therefore assessed as **Low** (loss of 25-75%) and resilience as **Medium**. Thus, the biotope is considered to have **Medium** sensitivity to organic enrichment, although the animals found within the biotope may be able to utilize some of the input of organic matter as food.

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

If the muddy fine sand that characterizes this biotope was replaced with soft or hard rock substrata, this would represent a fundamental change to the physical character of the biotope. Additionally, the infaunal community that occurs and characterizes the biotope could no longer be supported. The biotope would therefore be lost and/or re-classified.

Sensitivity assessment: Resistance to the pressure is considered **None**, and resilience **Very Low**. Sensitivity has been assessed as **High**.

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

Records indicate that SS.SSa.IMuSa.EcorEns occurs on muddy fine sand and medium to fine sand (Connor *et al.*, 2004). *Echinocardium cordatum*, occurs in a range of substrata, including fine to very fine muddy sand; sandy mud; fine to very fine sand with a fine silt fraction; medium to fine sand; slightly muddy sand; sand with some gravel; sand with gravel, pebbles and/or shingle (Tillin &

Tyler-Walters, 2014). Additionally, although this assessment is largely based on *Ensis ensis*, the biotope also supports populations of other species of razor shells. *Ensis siliqua* and *Ensis arcuatus* are the other two species of razor shells occurring in the British Isles, which are found in fine sand, coarse sand and fine gravel (Hill, 2006). Furthermore, Connor *et al.* (2004) suggested that the infaunal community of EcorEns is likely to overlap a number of other biotopes such as FfabMag, NcirBat, AalbNuc and AreISa. Each of these biotopes supports slightly different infaunal communities depending on the nature of the substratum based on variations from fine muddy sand, to medium to very fine sand, muddy sand and slightly mixed sediment, and fine sand and muddy sand, respectively.

Sensitivity assessment: The characterizing species of this biotope are likely to be resistant to a change in one Folk class from, for example, muddy sand to sandy mud. However, this would probably represent a fundamental change in the character of the biotope, and a change in the abundance of the characteristic species, resulting in the loss and/or re-classification of the biotope. Resistance is, therefore, assessed as **None** and resilience is **Very low** (the pressure is a permanent change) and sensitivity is assessed as **High**.

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

Muddy sand communities are highly unlikely to be resistant of substratum loss because most species are infaunal and extraction of substratum to 30 cm is likely to result in the removal of the biological community along with substrata, including the characterizing species. A few mobile demersal species like the crab *Liocarcinus depurator* may be able to avoid the factor but even fast moving polychaetes are likely be removed during substratum loss. For example, dredging operations, were shown to affect large infaunal and epifaunal species, decrease sessile polychaetes and reduce numbers of burrowing heart urchins (Eleftheriou & Robertson, 1992). Furthermore, Hall *et al.* (1990) conducted a study to analyse the interaction between fishing and natural disturbance events. As a result of suction dredging for razor clam *Ensis* spp., 3.5 x 0.6 m pits were dug into the sediment, and significant reductions in the abundance of large proportions of the species on site were observed.

Sensitivity assessment. Due to the nature of this pressure it is highly likely that a large amount of the sediment would be removed along with the biological community, resulting in the removal of the biotope. Resistance is therefore assessed as **None** and resilience as **Medium** with a sensitivity of **Medium** to extraction of substratum to 30 cm.

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

The two key species in the biotope, *Echinocardium cordatum* and *Ensis ensis* are infaunal found close to the sediment surface. This life habit provides some protection from abrasion at the surface only. *Echinocardium cordatum* has a fragile test that is likely to be damaged by an abrasive force, such as movement of trawling gear over the seabed. Bergman & van Santbrink (2000) suggested that *Echinocardium cordatum* was one of the most vulnerable species to trawling, and substantial reductions in the numbers of the species due to physical damage from scallop dredging have been observed (Eleftheriou & Robertson, 1992). *Echinocardium cordatum* was reported to suffer between 10 and 40% mortality due to fishing gear, depending on the type of gear and sediment after a single trawl event (Bergman & van Santbrink, 2000), with mortality possibly increasing to 90% in summer when individuals migrate to the surface of the sediment during their short reproductive season.

Bivalves such as *Ensis* spp., together with starfish have been reported to be relatively resistant (Bergman & van Santbrink, 2000). However, Eleftheriou & Robertson (1992) observed large numbers of *Ensis ensis* killed or damaged by dredging operations and Gaspar *et al.* (1998) reported high levels of damage in *Ensis siliqua* from fishing.

Upper burrow structures of species occupying the sediment may collapse by passing fishing gear, and although they may be rapidly reconstructed (Atkinson pers. com., cited in Jennings & Kaiser, 1998), the energetic costs of repeated burrow reconstruction may have long-term implications for the survivorship of individuals (Jennings & Kaiser, 1998). In the event of damage caused to species such as heart urchins, molluscs and crustaceans as a result of this pressure, damaged or undamaged animals are likely to experience increased predation pressure either at low (birds) or high tide (fish and crabs).

SS.SSa.IMuSa.EcorEns occurs in medium to fine sand and slightly muddy sand (Connor *et al.*, 2004). Abrasion events caused by a passing fishing gear, or scour by objects on the seabed surface are likely to have marked impacts on the substratum and cause turbulent re-suspension of surface sediments. When used over fine muddy sediments, trawls are often fitted with shoes designed to prevent the boards digging too far into the sediment (M.J. Kaiser, pers. obs., cited in Jennings & Kaiser, 1998). The effects may persist for variable lengths of time depending on tidal strength and currents and may result in a loss of biological organization and reduce species richness (Hall, 1994; Bergman & van Santbrink, 2000; Reiss *et al.*, 2009) (see change in suspended solids and smothering pressures).

Sensitivity assessment. The infaunal position provides some protection but the characterizing species of the biotope may suffer some damage as a result of surface abrasion. Resistance is therefore assessed as **Low** and resilience as **Medium** so the biotope's sensitivity is assessed as **Medium.**

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

The two key species in the biotope, *Echinocardium cordatum* and *Ensis ensis* are infaunal found close to the sediment surface. The biotope occurs in medium to fine sand and slightly muddy sand (Connor *et al.*, 2004). Penetrative activities (e.g. anchoring, scallop or suction dredging) and damage to the seabed's sub-surface is likely to remove and/or damage the infaunal community, including the characterizing species of the biotope, given the fragility of the tests and that bottom fishing gears penetrate deeper into softer sediments (Bergman & van Santbrink, 2000). Bergman & van Santbrink (2000) suggested that *Echinocardium cordatum* was one of the most vulnerable species to trawling, and substantial reductions in the numbers of the species due to physical damage from scallop dredging have been observed (Eleftheriou & Robertson, 1992). *Echinocardium cordatum* was reported to suffer between 10 and 40% mortality due to fishing gear, depending on the type of gear and sediment after a single trawl event (Bergman & van Santbrink, 2000), with mortality possibly increasing to 90% in summer when individuals migrate to the surface of the sediment during their short reproductive season.

Bivalves such as *Ensis* spp., together with starfish have been reported to be relatively resistant possibly given their ability to burrow deeper into the sediment (Bergman & van Santbrink, 2000). However, Eleftheriou & Robertson (1992) observed large numbers of *Ensis ensis* killed or damaged by dredging operations and Gaspar *et al.* (1998) reported high levels of damage in *Ensis siliqua* from fishing. A study by Haunton *et al.* (2007) analysed the correlation between hydraulic dredge efficiency and razor clam population annual production and found that gears of the current design are highly efficient and remove approx. 90% of the population in a single tow, which is likely to result in total removal of the population in the towed area.

In the event of damage caused to species such as heart urchins, molluscs and crustaceans as a result of this pressure, damaged or undamaged animals are likely to experience increased predation pressure either at low (birds) or high tide (fish and crabs).

Penetrative events caused by a passing fishing gear are also likely to have marked impacts on the substratum and cause turbulent re-suspension of surface sediments. When used over fine muddy sediments, trawls are often fitted with shoes designed to prevent the boards digging too far into the sediment (M.J. Kaiser, pers. obs., cited in Jennings & Kaiser, 1998). The effects may persist for variable lengths of time depending on tidal strength and currents and may result in a loss of biological organization and reduce species richness (Hall, 1994; Bergman & van Santbrink, 2000; Reiss *et al.*, 2009) (see change in suspended solids and smothering pressures).

Sensitivity assessment: The biotope could be lost or severely damaged, depending on the scale of the activity (see abrasion pressure). Therefore, a resistance of **None** is suggested. Resilience is probably **Medium**, and therefore the biotope's sensitivity to this pressure if likely to be **Medium**.

Changes in suspended solids (water clarity)	High Q: Medium A: Medium C: Medium	High Q: High A: High C: High	Not sensitive Q: Medium A: Medium C: Medium

Changes in suspended sediment and siltation rate (resulting from changes in the hydrographic regime, run-off from the land or coastal construction) are likely to result in changes in the sediment composition of the surface layers and hence the communities present. Increased suspended sediment may lead to decreased light penetration, possible clogging of feeding organs of suspension feeders such as *Ensis ensis*, and the possibility of smothering of whole organisms (see smothering pressure). However, community members of this biotope live beneath the sediment surface or are mobile, and are unlikely to be directly exposed to changes in suspended solids. Probert (1981) reported *Echinocardium cordatum* in high numbers in the Bay of Mevagissey, Cornwall, for example, where fine-grained mineral waste from the china clay industry was dumped over many years, suggesting that this species is likely to be resistant to increases in siltation. In addition, studies by Gilbert *et al.* (2007) on sediment re-working coefficients reported that *Echinocardium cordatum* is capable of high sediment re-working rates, suggesting that this species is therefore likely to play an important role in mitigating the effects of increased siltation, that may result from an increase in suspended solids in the biotope.

An increase in turbidity, reducing light availability will reduce primary production in the biotope. However, the majority of productivity in SS.SSa.IMuSa.EcorEns is secondary (detritus) and so is not likely to be significantly affected by changes in turbidity. Nevertheless, primary production by pelagic phytoplankton and microphytobenthos do contribute to benthic communities and long-term increases in turbidity may reduce the overall organic input to the detritus. Species such as *Echinocardium cordatum* feeds on detritus that accumulate on the bottom and so its growth consequently relies on the regular supply of detritus (Ridder de *et al.*, 1991).

Holme (1954) reported that *Ensis ensis* is the more silt resistant of the British *Ensis* species and is generally found at sheltered localities or from offshore and in sediments with a silt percentage of up to 16%. However, an increased in suspended solids in the water can considerably reduce the quantity of dissolved oxygen, as well as increase the production of mucous to protect the gills from clogging, which consequently can impair metabolism of filter-feeding bivalves, such as *Ensis* spp. (Moore, 1977). A decrease in siltation may equally affect growth and fecundity if the supply of organic particulate matter declines, given that the particles taken are not discriminated upon nutritional value (Moore, 1977 references therein).

Sensitivity assessment: The key species in the biotope, *Echinocardium cordatum* and *Ensis ensis*, are likely to be resistant to changes in suspended sediment and the species composition of the biotope is not likely to be drastically affected at the benchmark level. Resistance is assessed as **High** and resilience as **High** (by default)**.** The biotope is therefore assessed as **Not Sensitive** at the pressure benchmark level.

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

The biotope is characterized by burrowing species such as the heart urchin *Echinocardium cordatum*, razor shells *Ensis* spp., polychaete worms and bivalves, and mobile species such as crabs, fish and other molluscs, that are likely to be able to burrow upwards and therefore unlikely to be adversely affected by smothering of 5 cm sediment. Bijkerk (1988, results cited from Essink, 1999) indicated that the maximal overburden through which *Echinocardium cordatum* could migrate was approximately 30 cm in sand, but no further information was available on the rates of survivorship or the time taken to reach the surface. *Ensis* spp. have a large foot and are rapid, deep burrowers (Fish & Fish, 1996), and are therefore likely to be able to adapt their positioning in the substratum in response to a deposition of sediment. The character of the overburden would however determine the degree of the impact on the biotope. For example, smothering by other material, especially oil, could result in the death of most species in the biotope. Furthermore, the biotope occurs within a range of wave exposure conditions from sheltered to exposed, and a range of tidal streams from very weak to moderately strong (Connor *et al.*, 2004). Dispersion of fine sediments may be rapid, and this could mitigate the magnitude of this pressure by reducing the time exposed, as 'light' deposition of sediments is likely to be cleared in a few tidal cycles in areas of higher water flow.

Sensitivity assessment: The characterizing species in this biotope are burrowers and therefore likely to be able to move within the sediment deposited as a result of a deposition of 5 cm of sediment. Resistance is assessed as **High** and resilience as **High** (by default) and the biotope is considered **Not Sensitive** to this pressure at the benchmark level.

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

The biotope is characterized by burrowing species such as the heart urchin *Echinocardium cordatum*, razor shells *Ensis* spp., polychaete worms and bivalves, and mobile species such as crabs, fish and other molluscs, that are likely to be able to burrow upwards or escape. Bijkerk (1988, results cited from Essink, 1999) indicated that the maximal overburden through which *Echinocardium cordatum* could migrate was approximately 30 cm in sand, but no further information was available on the rates of survivorship or the time taken to reach the surface. *Ensis* spp. have a large foot and are rapid, deep burrowers (Fish & Fish, 1996), and are therefore likely to be able to adapt their positioning in the substratum in response to a deposition of sediment. The character of the overburden would however determine the degree of the impact on the biotope. For example, smothering by other material, especially oil, could result in the death of most species in the biotope. Furthermore, the biotope occurs within a range of wave exposure conditions from sheltered to exposed, and a range of tidal streams from very weak to moderately strong (Connor *et al.*, 2004). Dispersion of fine sediments resulting from a 'heavy' deposition of sediment may take longer than a few tidal cycles to clear in the more sheltered examples of the biotope.

Sensitivity assessment: The characterizing species in this biotope are burrowers and therefore likely to be able to move within deposited sediment. However, a deposition of 30 cm of fine sediment is likely to result in a significant overburden of the infaunal species and there may be some mortality of the characterizing species as a result. Resistance is therefore assessed as **Medium** and resilience as **High** and the biotope is considered to have **Low** sensitivity to this pressure at the benchmark level.

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 was 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

No relevant evidence of sound or vibration reception in echinoids was found. *Ensis ensis* may respond to sound vibrations, retracting into the sediment, but the species is unlikely to be sensitive to noise disturbance at the pressure benchmark level.

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

SS.SSa.IMuSa.EcorEns is a sublittoral biotope, only occasionally occurring on the lower shore (Connor *et al.*, 2004). Although eelgrass *Zostera marina* may occasionally occur in low densities (Connor *et al.*, 2004), the biotope is not characterized by the presence of primary producers and is, therefore, not directly dependent on sunlight.

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. Barriers and changes in tidal excursion are 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.

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

With the exception of mobile predators, most of the species in this biotope are infaunal and therefore, not likely to be sensitive to visual disturbance. Mobile predators, like *Liocarcinus depurator*, are likely to be very sensitive and respond to shadows and movement as an adaptive response to predation. However, this is unlikely to significantly affect the nature of the biotope, nor its characterizing species composition.

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

Introduction or spread of invasive non-indigenous species	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

The north American razor shell *Ensis directus* (syn. *Ensis americanus)* was introduced into Britain via Europe and was found in Norfolk in 1989 (Palmer, 2004). Although it is widespread and has successfully established large populations, no direct impacts on native species or communities have been reported (Armonies & Reise, 1999; Palmer, 2004) Nevertheless, should local species be replaced by the American razor shell the nature of the biotope should be little altered. No other alien species are known to represent a threat to characterizing species in the biotope at present.

Sensitivity assessment: Based on the evidence presented, the biotope is unlikely to be impacted by the introduction of non-indigenous invasive species at present. Resistance is therefore assessed as **High** and resilience as **High** (by default), and the biotope is considered **Not Sensitive**.

Introduction of microbial pathogens	High Q: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High

There is little information on microbial pathogen effects on the characterizing species of this biotope. The occurrence of several parasitic gregarine protozoans, such as *Urospora neapolitana*, have been observed in the body cavity of *Echinocardium cordatum* (Coulon & Jangoux, 1987) although no reports of disease related mortalities were found. Viruses similar to Papillomavirus and Polyomavirus were detected in the digestive glands of *Ensis magnus (syn. Ensis arcuatus*) in

Spain (Ruíz *et al*., 2011, cited in López *et al*., 2012). Disseminated neoplasms (a type of tumour) were also reported in *Ensis siliqua* in Spain (López *et al*., 2011) including gonadal types (germinomas) in *Ensis magnus* (syn. *Ensis arcuatus*) and *Ensis siliqua*. However, epidemic mortalities seem to have not been observed (López *et al*., 2011). The limited field observations suggest that germinomas display slow progression, with a low mortality rate, and that the most significant damage produced is a reduction in the capacity to reproduce (Ruiz & López, 2012). No information regarding disease and pathogens on *Ensis* spp. in the British Isles was found. *Liocarcinus depurator* is known to suffer from Black Necrotic disease caused by a bacteria, although no information was available on mortality effects. If numbers are reduced predatory effects may decrease but this is not likely to have an impact on overall species diversity.

Sensitivity assessment: No evidence of losses of this biotope due to disease were found and it is likely that microbial pathogens will have only a minor possible impact on this biotope. Resistance and resilience are therefore assessed as **High** and the biotope judged as **Not Sensitive** to the introduction of microbial pathogens.

Removal of target species	None Q: High A: High C: High	Medium Q: High A: High C: High	Medium Q: High A: High C: High

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The sensitivity assessment for this pressure considers any biological/ecological effects resulting from the removal of target species on this biotope. Razor shell clams have high economic value and are often targeted by fisheries. Fishing methods include hand digging, 'salting', diving, traditional and hydraulic dredging. A study by Haunton *et al.* (2007) analysed the correlation between fishing efficiency and population annual production and found that gears of the current design are highly efficient and remove approx. 90% of the population in a single tow. Their analysis suggested that a high catch efficiency, together with the relatively slow growth of these species was likely to represent a real danger to the sustainability of this fishing industry and for *Ensis* populations. In Scotland, some subtidal razor shell beds are dense enough to be exploited commercially and the species has been harvested by suction dredges (Fowler, 1999). Although *Echinocardium cordatum* is not targeted by fisheries, dredging operations may adversely affect this species by removal or damage. Crabs such *as Liocarcinus depurator* are often extracted as a by-catch species in benthic trawling. A reduction in the density of predators may affect species abundance but is not likely to have a significant effect on overall species diversity.

Sensitivity assessment: Loss of either or both of the characterizing species is likely to result in the loss of the biotope. Resistance is therefore assessed as **None** (loss of >75% of selected species) and resilience as **Medium** resulting in the biotope being considered to have **Medium** sensitivity to removal of targeted species.

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

Direct, physical impacts are assessed through the abrasion and penetration of the seabed pressures, while this pressure considers the ecological or biological effects of by-catch. *Echinocardium cordatum* and *Ensis* spp., the characterizing species of this biotope, may be damaged or directly removed by static or mobile gears that are targeting other species, with reports of high levels of mortality of both characterizing species (see abrasion and penetration of the seabed pressures).

Commercial fisheries may discard damaged or dead non-target species, which could result in increased available food supply to detritus feeding *Echinocardium cordatum* that may have survived in the area targeted by fisheries, but may also attract mobile predators and scavengers including fish and crustaceans which may alter predation rates in the biotope.

Sensitivity assessment. Unintentional removal of the characterizing species would substantially alter the character of the biotope leading to re-classification. For example, Bergman & van Santbrink (2000) reported 10-40% mortality of *Echinocardium cordatum* due to fishing gear after one trawl event, possibly increasing to 90% in summer when individuals migrate to the surface of the sediment during their short reproductive season; and Eleftheriou & Robertson (1992) observed large numbers of *Ensis ensis* killed or damaged by dredging operations. Thus, the biotope is considered to have **Low** resistance to this pressure and to have **Medium** resilience. Sensitivity is therefore **Medium**.

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