Philine quadripartita and *Virgularia mirabilis* in soft stable infralittoral mud

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

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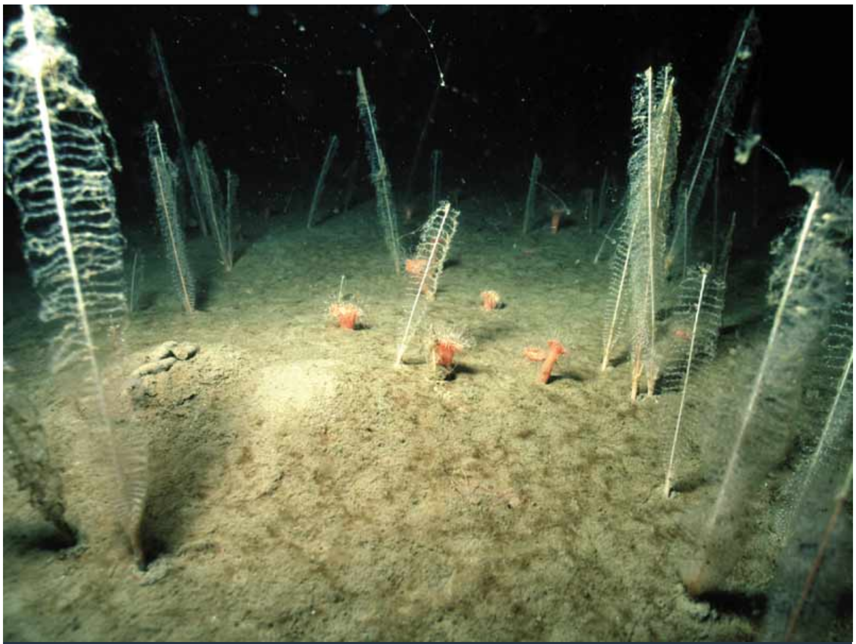
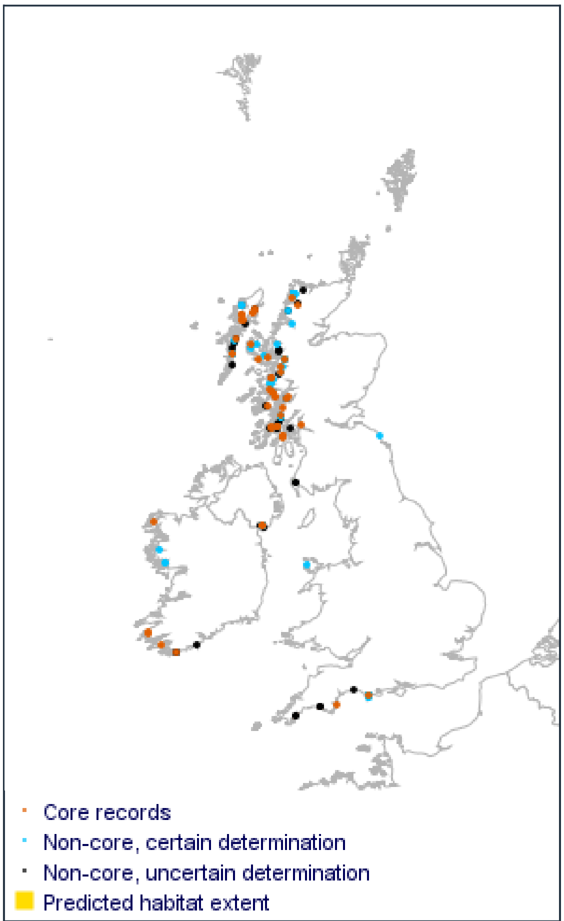


Dense *Virgularia* and *Sagartiogeton*.
Photographer: Keith Hiscock



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

Researched by Dr Harvey Tyler-Walters & Jacqueline Hill **Refereed by** Dr David Hughes

Summary

UK and Ireland classification

EUNIS 2008	A5.343	*Philine aperta* and *Virgularia mirabilis* in soft stable infralittoral mud
JNCC 2015	SS.SMu.IFiMu.PhiVir	*Philine aperta* and *Virgularia mirabilis* in soft stable infralittoral mud
JNCC 2004	SS.SMu.IFiMu.PhiVir	*Philine aperta and Virgularia mirabilis* in soft stable infralittoral mud
1997 Biotope	SS.IMU.MarMu.PhiVir	*Philine aperta and Virgularia mirabilis* in soft stable infralittoral mud

Description

Stable muds, occasionally with small stones, with a high proportion of fine material (typically greater than 80%) may contain the opisthobranch *Philine quadripartita* and the sea pen *Virgularia* *mirabilis*. These muds typically occur in shallow water down to about 12-15 m where significant seasonal variation in temperature is presumed to occur. This habitat is restricted to the most sheltered basins in, for example, sea lochs. Although most records suggest full salinity conditions are prevalent, some sites may be subject to variable salinity. *Philine quadripartita* is the most characteristic species of this habitat, occurring in high densities at many sites, whilst *Virgularia mirabilis*, a species found more widely in muddy sediments, appears to reach its highest densities in this shallow mud but may not be present in all examples of this biotope. Other conspicuous species found in this shallow muddy habitat include *Cerianthus lloydii*, *Pagurus bernhardus*, *Sagartiogeton* spp. and *Hydractinia echinata*. Burrowing crustacean megafauna, characteristic of deeper mud, are rare or absent from this shallow sediment although *Nephrops norvegicus* may sometimes be recorded. This biotope has been primarily recorded on the basis of its epifauna and a few conspicuous infauna. Little data exists on the infaunal component of this biotope but it may include *Nephtys* spp., spionid polychaetes, *Ampelisca* spp. and the bivalves *Nucula* spp., *Thyasira flexuosa*, *Kurtiella bidentata* and *Abra* spp. In the south of Great Britain, the polychaete *Sternaspis scutata* is also characteristic of this biotope. This polychaete is rare in Great Britain (Sanderson 1996). This southern variant of the biotope is very restricted in the UK to Portland Harbour but is known to occur further south in the Gulf of Gascony and the Mediterranean. (Information from Connor *et al*., 2004).

Depth range

5-10 m, 10-20 m

Additional information

Records of *Philine quadripartita* in the British Isles were misidentified as *Philine aperta* (Price *et al*., 2011). Outwardly, most species of *Philine* are very similar in morphology and a detailed examination of their internal anatomy, especially the shape of the internal shell, gizzard and penial papilla, is required to differentiate the species (Price *et al*., 2011). *Philine aperta* is recorded from South Africa and Mozambique while *Philine quadripartita* is recorded from the North East Atlantic and the Mediterranean.

Listed By

- none -

Further information sources

Search on:

G 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. *Virgularia mirabilis* and *Philine quadripartita* are functionally dissimilar and are not necessarily associated with each other but occur in the same muddy sediment habitats. There is no information regarding possible interactions between any of the other species in the biotope but there seems to little interdependence. Burrowing species which are present create tunnels in the sediment which themselves provide a habitat for other burrowing or inquilinistic species.
- *Virgularia mirabilis* might be adversely affected by high levels of megafaunal bioturbation, perhaps by preventing the survival of newly settled colonies.
- Many of the species living in deep mud biotopes are generally cryptic in nature and not usually subject to predation. Evidence of predation on *Virgularia mirabilis* by fish seems limited to a report by Marshall & Marshall (1882 in Hoare & Wilson, 1977) where the species was found in the stomach of haddock. Many specimens of *Virgularia mirabilis* lack the uppermost part of the colony which has been attributed to nibbling by fish. Observations by Hoare & Wilson (1977) suggest however, that predation pressure on this species is low. The sea slug *Armina loveni* is a specialist predator of *Virgularia mirabilis*.
- *Nephrops norvegicus* is known to be eaten by a variety of bottom-feeding fish, including cod, haddock, skate and dogfish. *Symbion pandora*, a tiny sessile animal less than 1 mm long, lives commensally on the mouthparts of *Nephrops norvegicus*.
- Brittlestars are common, with *Amphiura chiajei* predominating on finer muds. Most of these animals are deposit-feeders, ingesting tiny organic particles and feeding on the bacterial layer coating the sediment grains. If present in high abundance the burrowing and feeding activities of *Amphiura chiajei* can modify the fabric and increase the mean particle size of the upper layers of the substrata by aggregation of fine particles into faecal pellets. Such actions create a more open fabric with a higher water content which affects the rigidity of the seabed (Rowden *et al*., 1998(b)). Such destabilisation of the seabed can affect rates of particle resuspension.
- The hydrodynamic regime, which in turn controls sediment type, is the primary physical environmental factor structuring benthic communities such as IMU.PhiVir. The hydrography also 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.

Seasonal and longer term change

- Species such as the sea pen *Virgularia mirabilis* and *Amphiura chiajei* appear to be long-lived and are unlikely to show any significant seasonal changes in abundance or biomass. Seapen faunal communities appear to persist over long periods at the same location. Movement of the sea pen *Virgularia mirabilis* in and out of the sediment may be influenced by tidal conditions (Hoare & Wilson, 1977).
- The numbers of some of the other species in the biotope may show peak abundances at certain times of the year due to seasonality of breeding and larval recruitment.

Habitat structure and complexity

The biotope has very little structural complexity with most species living in or on the sediment. Burrowing megafauna are generally rare or absent, therefore there will be few burrows available for colonization. Several species, such as the sea pen *Virgularia mirabilis* and the anemone *Cerianthus lloydii*, extend above the sediment surface. However, apart from a couple of species of nudibranch living on the sea pens and the tubiculous amphipod *Photis longicaudata* associated with *Cerianthus lloydii* (Moore & Cameron, 1999) these species do not provide significant habitat for other fauna. Excavation of sediment by infaunal organisms, such as errant polychaetes and *Philine quadripartita*, ensures that sediment is oxygenated to a greater depth allowing the development of a much richer and/or higher biomass community of species within the sediment.

Productivity

Productivity in subtidal sediments is often quite low. Macroalgae are absent from IMU.PhiVir 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 are recycled.

Recruitment processes

- *Philine quadripartita*, *Virgularia mirabilis* and other major component species in sea pen biotopes appear to have a plankton stage within their life cycle.
- The reproductive biology of British sea pens has not been studied, but in other species, for instance *Ptilosarcus guerneyi* from Washington State in the USA, the eggs and sperm are released from the polyps and fertilization takes place externally. The free-swimming larvae do not feed, and settle within seven days if a suitable substratum is available (Chia & Crawford, 1973). Dispersal of *Virgularia mirabilis* planulae is therefore likely to be limited to relatively short distances suggesting that populations may not be replenished from distant sources (David Hughes, pers. comm.). The limited data available from other species would suggest a similar pattern of patchy recruitment, slow growth and long lifespan for *Virgularia mirabilis*.

Time for community to reach maturity

Very little is known about the population dynamics and longevity of *Virgularia mirabilis* in Britain, however information from other species suggest that this species is likely to be long-lived and slow growing with patchy and intermittent recruitment. Other burrowing species representative of this biotope vary in longevity and reproductive strategies.

Additional information

No text entered

Preferences & Distribution

Habitat preferences

Depth Range	5-10 m, 10-20 m
Water clarity preferences	
Limiting Nutrients	Nitrogen (nitrates), Phosphorus (phosphates)
Salinity preferences	Full (30-40 psu)
Physiographic preferences	Enclosed coast / Embayment
Biological zone preferences	Infralittoral
Substratum/habitat preferences	Mud
Tidal strength preferences	Very Weak (negligible)
Wave exposure preferences	Extremely sheltered, Very sheltered
Other preferences	

Additional Information

This biotope can be found in water less than 10 m deep in the sheltered inner basins of some sea lochs (Howson *et al*., 1994)

Species composition

Species found especially in this biotope

Rare or scarce species associated with this biotope

- *Sternapsis scutata*

Additional information

May contain the nationally rare polychaete *Sternapsis scutata* in southern Great Britain.

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

Philine quadripartita and *Virgularia mirabilis* are the main important characterizing species, giving the name to the biotope. *Cerianthus lloydii* is another characteristic member of the epifauna. *Amphiura filiformis* may be abundant but reaches higher abundance in SMU.IFiMu.BriAchi. Other members of the infauna are probably found in a range of other biotope in similar sediments, while the other species are mobile (e.g. crabs and hermit crabs) or restricted to stones or shells (e.g. *Hydractinia*). Connor *et al.* (2004) note that this biotope might represent a temporal variant of similar SMU biotopes as the abundance of *Philine quadripartita* may vary from year to year.

Therefore, the assessment of sensitivity is based on the important characterizing species *Philine quadripartita* and *Virgularia mirabilis* and the mud habitat. The sensitivity of other species is discussed where relevant.

Resilience and recovery rates of habitat

Philine quadripartita (studies as *aperta*) is a simultaneous hermaphrodite, capable of producing both eggs and sperm (Lancaster, 1983). In Britain, spawning is thought to occur between April and September (Thompson, 1976; Lancaster, 1983). It lays eggs in flask-shaped eggs in masses of up to 50,000. Eggs hatch within 3.5 to 8 days depending on temperature. The veliger larvae are ready for metamorphosis and settlement within 30-40 days (in the laboratory) (Thompson, 1976; Lancaster, 1983; Thompson, 1988; Hansen, 1991; Hansen & Ockelmann, 1991). It has a lifespan of 3-4 years (Thompson, 1976). *Philine quadripartita* is widely distributed around the coasts of Britain.

Little evidence was found to support this resilience assessment for *Cerianthus lloydii*. MES (2010) suggested that the genus *Cerianthus* would be likely to have a low recovery rate following physical disturbance based on long lifespan and slow growth rate. The MES (2010) review also highlighted that there were gaps in information for this species and that age at sexual maturity and fecundity is unknown although the larvae are pelagic (MES 2010). No empirical evidence was found for recovery rates following perturbations for *Cerianthus lloydii*. This species has limited horizontal mobility and re-colonization via adults is unlikely (Tillin & Tyler-Walters, 2014).

Little information on the reproduction and life history of *Virgularia mirabilis* was found. Edwards & Moore (2009) noted that many sea pens exhibited similar characteristics. Recent studies of oogenesis in *Funiculina. quadrangularis* and *Pennatula phosphorea* in Loch Linnhe, Scotland, demonstrated that they were dioecious, with 1:1 sex ratios, highly fecund, with continuous prolonged oocyte development and annual spawning (Edwards & Moore 2008; Edwards & Moore 2009). In *Pennatula phosphorea*, oogenesis exceeded 12 months in duration, with many small oocytes of typically 50 per polyp giving an overall fecundity of ca 40,000 in medium to large specimens, depending on size. However, <30% matured (synchronously) and were spawned in summer (July-August). Mature oocytes were large (>500µm) which suggested a lecithotrophic larval development (Edwards & Moore, 2008). In *Funiculina. quadrangularis* fecundity was again high, expressed as 500-2000 per 1 cm midsection, but not correlated with size, and again, only a small proportion of the oocytes (<10%) matured. Unlike *Pennatula phosphorea*, annual spawning occurred in autumn or winter (between October and January). Also the mature oocytes were very large (>800µm), which suggested a lecithotrophic larval development (Edwards &Moore, 2009). In a study of the intertidal *Virgularia juncea* fecundity varied with length (46,000 at 50 cm and 87,000 at 70 cm), reached a maximum size of 200-300 µm in May and were presumed to be spawned between August and September (Soong, 2005). Birkland (1974) found the lifespan of *Ptilosarcus gurneyi* to be 15 years, reaching sexual maturity between the ages of 5 and 6 years; while Wilson *et al.* (2002) noted that larger specimens of a tall sea pen (*Halipteris willemoesi*) in the Bering Sea were 44 years old, with a growth rate of 3.6 - 6.1cm/year.

Hughes (1998a) suggested that patchy recruitment, slow growth and long lifespan were typical of sea pens. Larval settlement is likely to be patchy in space and highly episodic in time with no recruitment to the population taking place for some years. Greathead *et al.* (2007) noted that patchy distribution is typical for sea pen populations. In Holyhead harbour, for example, animals show a patchy distribution, probably related to larval settlement (Hoare and Wilson, 1977).

Virgularia mirabilis was found to withdraw into its burrow rapidly (ca 30 seconds) and could not be uprooted by dragged creels (Hoare and Wilson, 1977; Eno *et al*., 2001; Ambroso *et al*., 2013). In summary, British sea pen species have been found to recover rapidly from the effects of dragging, uprooting and smothering (Eno *et al*., 2001). Recovery from effects that remove a proportion of the sea pen population (e.g. bottom gears, hydrographic changes) will depend on recruitment processes and little is known about the life history and population dynamics of sea pens (Hughes, 1998a).

Resilience assessment. No information on the population dynamics of *Philine quadripartita* was found. However, it is highly fecund, with high potential larval dispersal range so that recruitment is probably good, and it is a mobile species, capable of recolonizing the affected area adjacent populations, especially as it is common in British waters. Therefore, *Philine quadripartita* population s would probably recover within a couple of years (resilience is 'High'). However, there is little information regarding the resilience of *Cerianthus lloydii.* A resilience of 'Medium' (2 – 10 years) is suggested for all resistance levels ('None', 'Low', 'Medium' or 'High') based on expert judgement. Where *Virgularia mirabilis* survive impact undamaged, that is resistance is 'High', recovery is likely to be rapid; a resilience of 'High' (<2 years). Where a proportion of the population is removed or killed, then the species has a high dispersal potential and long-lived benthic larvae, but larval recruitment is probably sporadic and patchy and growth is slow, suggesting that recovery may take many years: a resilience of 'Low' (>10 years). Therefore, the resilience of the biotope is likely to be Low (>10 years) as *Virgularia mirabilis* and *Cerianthus lloydii* are likely to take many years to recover. The assessment is based on the reproduction and life history characteristics of the important characteristic species, or similar species, rather than direct evidence. Therefore, while confidence in the quality of the evidence and its concordance is Medium, confidence its application in Low.

Hydrological Pressures

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

In shallow sea lochs, sedimentary biotopes typically experience seasonal changes in temperature between 5°C and 15°C (10°C) (Hughes, 1998a). Although, unusually warm summers or cold winters may change the temperatures outside this range, benthic burrowing species will be buffered from extremes by their presence in the sediment.

Spawning, hatching, and time to metamorphosis are all temperature dependent in *Philine quadripartita* (as *aperta*). Spawning occurs during the warmest months of the year (April to August)

(Lancaster, 1983). Laboratory results showed hatching occurred after 3.5 days at 23°C and 8 days at 13°C (Thompson, 1976) and time to metamorphosis occurred after 35-40 days at 12-13°C and 30 days at 15°C (Hansen & Ockelmann, 1991). *Philine quadripartita* is widely distributed around the coasts of Britain, south to the Mediterranean (Thompson, 1976).

Sea pens can withdraw into their burrows for protection. No information was found on the upper limit of sea pens tolerance to temperature. *Virgularia mirabilis* is recorded from western Europe, the Mediterranean, from Norway and Iceland to Africa in the North Atlantic, and to the Gulf of Mexico in North America (Hughes, 1998a; OBIS 2015). Jones *et al.* (2000) suggested that *Virgularia mirabilis* was probably more tolerant of temperature change than other British sea pen species due to its abundance in shallow waters.

Cerianthus lloydii adults are locally abundant in many localities on all coasts of the British Isles and in some areas are common on the shore. This species occurs on all western coasts of Europe from Greenland and Spitzbergen south to Biscay. Larvae, but not adults, have been recorded from the Mediterranean. However, no further information on the temperature tolerance of *Cerianthus lloydii* was found.

The distribution of *Virgularia mirabilis*, *Cerianthus lloydii*, and *Philine quadripartita* suggest that they are probably resistant of 2°C change in temperature for a year. Exposure to short-term acute change of 5°C may interfere with reproduction in *Philine quadripartita* and may cause *Virgularia mirabilis*, *Cerianthus lloydii* to withdraw into their burrows temporarily. However, there is no evidence to suggest that mortality would result. Therefore, a resistance of **High** is suggested but with Low confidence. Therefore, resilience is **High**, so that the biotope is probably **Not sensitive** at the benchmark level.

Temperature decrease (local)	High Q: Medium A: Low C: Medium	High Q: High A: High C: High	Not sensitive Q: Medium A: Low C: Medium

In shallow sea lochs, sedimentary biotopes typically experience seasonal changes in temperature between 5°C and 15°C (10°C) (Hughes, 1998a). Although, unusually warm summers or cold winters may change the temperatures outside this range, benthic burrowing species will be buffered from extremes by their presence in the sediment.

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Greenland and Spitzbergen south to Biscay. Larvae, but not adults, have been recorded from the Mediterranean. Crisp (1964) reported that *Cerianthus lloydii* in North Wales were apparently unaffected by the severe winter of 1962/63. However, no further information on the temperature tolerance of *Cerianthus lloydii was found.*

The distribution of *Virgularia mirabilis*, *Cerianthus lloydii*, and *Philine quadripartita* suggest that they are probably resistant of 2°C change in temperature for a year. Exposure to short-term acute change of 5°C may interfere with reproduction in *Philine quadripartita* and may cause *Virgularia mirabilis*, *Cerianthus lloydii to withdraw into their burrows temporarily. However, there is no evidence to suggest that mortality would result.* Therefore, a resistance of **High** is suggested but with Low confidence. Therefore, resilience is **High**, so that the biotope is probably **Not sensitive** at the benchmark level.

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

No information on the salinity tolerance of the important characterizing species was found. *Cerianthus lloydii* may be recorded from the intertidal at LWST, but is probably protected from changes in salinity due to its infaunal habitat, buffered by the salinity of the interstitial water of the sediment. Greathead *et al.* (2007) demonstrated that *Virgularia mirabilis* was the most ubiquitous of all three of the sea pens in Scotland, found in habitats nearer coastal areas and inner sea lochs. Jones *et al.* (2000) suggested that *Virgularia mirabilis* was more tolerant of reduced salinity than other British sea pens due to its distribution in shallower waters. No information on the salinity preferences of *Philine quadripartita* was found.

An increase in salinity at the benchmark level, would result in a salinity of >40 psu, and as hypersaline water is likely to sink to the seabed, the biotope may be affected by hypersaline effluents. Ruso *et al.* (2007) reported that changes in the community structure of soft sediment communities due to desalinisation plant effluent in Alicante, Spain. In particular, in close vicinity to the effluent, where the salinity reached 39 psu, the community of polychaetes, crustaceans and molluscs was lost and replaced by one dominated by nematodes. Roberts *et al.* (2010b) suggested that hypersaline effluent dispersed quickly but was more of a concern at the seabed and in areas of low energy where widespread alternations in the community of soft sediments were observed. In several studies, echinoderms and ascidians were amongst the most sensitive groups examined (Roberts *et al*., 2010b).

Sensitivity assessment. This biotope (IFiMu.PhiVir) is recorded from full and variable salinity regimes. However, although the biotope might occur in sea lochs subject to variable salinity, the benthos may not experience variable salinity at depth, and infauna are protected from short-term changes in salinity due to the salinity of the interstitial waters. An increase in salinity at the benchmark level would result in a salinity of >40 psu. However, hypersaline effluent is likely to sink to the seabed and may affect the community. Based on the evidence from Ruso *et al.* (2007) and Roberts *et al.* (2010b) it is likely that the community will be degraded and, especially, *Philine quadripartita* will leave the affected area or be killed. The effect on sea pens and anemones is unknown. Therefore, a resistance of **Low** is suggested with Low confidence. Resilience is probably **Medium** so that the sensitivity is assessed as **Medium**.

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

No information on the salinity tolerance of the important characterizing species was found. *Cerianthus lloydii* may be recorded form the intertidal at LWST, but is probably protected from changes in salinity due to its infaunal habitat, buffered by the salinity of the interstitial water of the sediment. Greathead *et al.* (2007) demonstrated that *Virgularia mirabilis* was the most ubiquitous of all three of the sea pens in Scotland, found in habitats nearer coastal areas and inner sea lochs. Jones *et al.* (2000) suggested that *Virgularia mirabilis* was more tolerant of reduced salinity than other British sea pens due to its distribution in shallower waters. No information on the salinity preferences of *Philine quadripartita* was found.

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

The biotope (IFiMu.PhiVir) occurs in low energy environments with weak (<0.5 m/sec.) to very weak tidal streams (Connor *et al.* 2004), which are a prerequisite for the fine mud sediments characteristic of the biotope. *Virgularia mirabilis* is also recorded from coarser sandier muds with small stones and shell fragments e.g. SS.SMu.CSaMu.VirOphPmax (Hughes, 1998a; Greathead *et al.* 2007), and is probably more tolerant of current or wave induced flow than other British sea pens. Hiscock (1983) examined the effects of water flow on *Virgularia mirabilis.* As water flow rates increase, *Virgularia mirabilis* first responds by swinging polyps around the axial rod to face away from the current (at 0.12 m/s), then polyps face downstream. With further increase in flow, the stalk bends over and the pinnae are pushed together to an increasing amount with increasing velocity of flow (at 0.33 m/s). Finally, tentacles retract and at water speeds greater than 0.5 m/s (i.e. 1 knot) the stalk retracts into the mud (Hiscock, 1983). If water speeds remain at this level or above the sea-pen will be unable to extend above the sediment, unable to feed and could die (Hill & Wilson, 2000).

Cerianthus lloydii is recorded from biotopes with a wide range of water flow regimes, from very weak to strong flow and in muddy to mixed or coarse sediments (Connor *et al*., 1997a).Therefore, it is likely to tolerate changes in water flow regimes. However, *Philine quadripartita* is recorded from mud, muddy sand and sand (Thompson, 1976; Connor *et al*., 1997a).

Sensitivity assessment. This biotope is only recorded in muds and in weak or very weak flow (Connor *et al*., 2004), so that a further decrease in flow is not relevant. Increased flow has the potential to modify the sediment, especially at the surface. A significant increase in water flow may winnow away the mud surface or even remove the mud habitat and hence the biotope if prolonged. An increase of 0.2 m/s may begin to erode the mud surface where the site is already subject to flow (e.g. weak flow at the seabed), based on sediment erosion deposition curves (Wright, 2001). However, given the depth of mud that characterizes the biotope only the surface of the mud may be removed within a year. *Cerianthus lloydii* is unlikely to be impacted by a change in the sediment, and is a passive predator. *Philine quadripartita* is also found in coarser sediments but reaches a high abundance in this biotope, presumably due to the abundance of prey and or habitat stability. *Virgularia mirabilis* may be directly affected by an increase in flow, especially if it exceeds 0.5 m/s. Therefore, modification of the sediment, coupled with a reduction in the *Virgularia mirabilis* abundance may result in a loss this biotope as described by the classification. Therefore, a resistance of **Low** is recorded. Resilience is probably also **Low** so that sensitivity is assessed as **High**.

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

The pressure benchmark is relevant only to littoral and shallow sublittoral fringe biotopes.

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

The biotope (IFiMu.PhiVir) occurs in low energy environments sheltered or extremely sheltered from wave action (Connor *et al.* 2004), which are a prerequisite for the fine mud sediments characteristic of the biotope. *Virgularia mirabilis* occurs in coastal areas and inner sea lochs but these areas are still sheltered from wave action, and in sandier muds (e.g. the biotope SS.SMu.CSaMu.VirOphPmax) (Hughes, 1998a; Greathead *et al.* 2007), wave exposure was not recorded to be more than 'sheltered'. *Cerianthus lloydii* is recorded from biotopes from wave exposed to extremely sheltered muddy to mixed or coarse sediments (Connor *et al.*, 1997b). Therefore, it is likely to tolerate changes in wave action. However, *Philine quadripartita* is recorded from mud, muddy sand, and sand and very to extremely wave sheltered biotopes (Thompson, 1976; Connor *et al.*, 1997b).

Sensitivity assessment. A decrease in wave exposure is unlikely in the sheltered habitats they inhabit. An increase in wave exposure is likely to affect *Virgularia mirabilis* and *Philine quadripartita* species adversely, limiting or removing the shallower proportion of the population, and potentially modifying sediment and therefore habitat preferences in the longer-term. However, a 3-5% increase in significant wave height (the benchmark) is unlikely to be significant. The benchmark level of change may be no more than expected during winter storms even in the sheltered waters favoured by this biotope. Therefore, resistance is recorded as **High** at the benchmark level. Hence, resilience is **High** and the biotope is assessed as **Not sensitive** at the benchmark level.

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.

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

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

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

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

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

No evidence was found

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

Virgularia mirabilis is often found in sea lochs so may be able to tolerate some reduction in oxygenation. However, Jones *et al.* (2000) reported that sea pen communities were absent from areas which are deoxygenated and characterized by a distinctive bacterial community and Hoare & Wilson (1977) reported that *Virgularia mirabilis* was absent from sewage related anoxic areas of Holyhead harbour.

Nilsson & Rosenberg (1994) examined the effects of hypoxia on muddy sediment cores in mesocosm experiments. Both moderate (ca 1 mg O_2/l) and severe (ca 0.5 mg O_2/l) hypoxia resulted in a significant reduction in species abundance after 6-7 days of hypoxia. *Amphiura filiformis* left the sediment as hypoxia increases, followed by *Kurtiella bidentata* (as *Mysella bidentata* (0.5-2 days later), Echinocardium cordatum left the sediment before moderate hypoxia was reached, and all *Labidoplax buskii* left the sediment at 1.6 mg O_2/l, while *Nephtys hombergii* was the last species to leave the sediment. Almost all the *Philine quadripartita* (studied as *aperta*) left the sediment at both levels of hypoxia, and even escaped the experimental sediment cores, or died at the sediment surface. In moderate hypoxia most individuals survived but at severe hypoxia treatment only two individuals survived.

Diaz & Rosenberg (1995) noted that anemones include species that were reported to be particularly tolerant of hypoxia (e.g. *Cerianthus* sp and *Epizoanthus erinaceus*). A major hypoxic event due a pyncocline in the Gulf of Trieste resulted in a mass mortality of benthos between 12 and 26th September 1983 (Stachowitsch, 1992), during which the oxygen levels fell below 4.2 mg/l, became anoxic, and hydrogen sulphide and ammonia were released (Faganeli *et al.*, 1985). Amongst the epifauna, the even hypoxia resistant polychaetes and bivalves died after 4-5 days and the only organism to survive after one week were the anemones *Cerianthus* sp and *Epizoanthus erinaceus*, the gastropods *Aporrhais pespelecani* and *Trunculariapsis trunculus* and the sphinuculid *Sipunculus nudis* (Stachowitsch, 1992).

Sensitivity assessment. The evidence suggests that severe hypoxic or anoxic conditions are likely to be detrimental to sea pen and *Philine quadripartita*, while *Cerianthus lloydii* may survive even anoxic conditions for a week. Sea pens might be resistant of short-term hypoxia due to their presence at depth in sheltered sea lochs but severe hypoxia may be detrimental. However, a reduction in oxygen levels to below 2 mg/l for a week will probably force *Philine quadripartita* to leave the affected area, and result in a significant reduction in its abundance and the abundance of other infauna.

Therefore, a resistance of **Low** is suggested to represent to loss of a small proportion of the sea pen population but a significant proportion of the *Philine quadripartita* population. Resilience is probably **Low** due to time required for the sea pen population to recover, although the *Philine quadripartita* population would probably recover rapidly (< 2 years). Therefore, sensitivity is assessed as **High**.

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

Hoare & Wilson (1977) noted that *Virgularia mirabilis* was absent from part of the Holyhead Harbour heavily affected by sewage pollution. However, the species was abundant near the head of Loch Harport, Skye, close to a distillery outfall discharging water enriched in malt and yeast residues and other soluble organic compounds (Nickell & Anderson, 1977; cited in Hughes, 1998a), where the organic content of the sediment was up to 5%. *Virgularia mirabilis* was also present in Loch Sween in Scotland in sites where organic content was as high as 4.5% (Atkinson, 1989).

No information was available on the effect of nutrient enrichment on *Cerianthus lloydii or Philine quadripartita*. Borja *et al*. (2000) and Gittenberger and van Loon (2011) both assigned *Cerianthus lloydii* to their Ecological Group I, 'species very sensitive to organic enrichment and present under unpolluted conditions (initial state)' in of the AZTI Marine Biotic Index (AMBI) index to assess disturbance (including organic enrichment). The basis for their assessment and relation to the pressure benchmark is not clear.

Sensitivity assessment. Sublittoral muds may be expected to be high in organic nutrients, and the presence of *Virgularia mirabilis* in areas of up to 4.5% organic carbon (Atkinson, 1989) suggest a resistance to organic enrichment at the benchmark level. The high organic content suggests that nutrients are not limiting. But no evidence on the direct effects of nutrients in the form of nitrates, phosphates and silicates was found. Algal mats are associated with nutrient enrichment, but only in shallow waters but the biotope could be affected by the algal blooms that sink to the bottom when they die, although the main effects are organic enrichment and hypoxia. However, the biotope is assessed as **Not sensitive** at the pressure benchmark of compliance with good status as defined by the WFD.

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

Hoare & Wilson (1977) noted that *Virgularia mirabilis* was absent from part of the Holyhead Harbour heavily affected by sewage pollution. However, the species was abundant near the head of Loch Harport, Skye, close to a distillery outfall discharging water enriched in malt and yeast residues and other soluble organic compounds (Nickell & Anderson, 1977; cited in Hughes, 1998a), where the organic content of the sediment was up to 5%. *Virgularia mirabilis* was also present in Loch Sween in Scotland in sites where organic content was as high as 4.5% (Atkinson, 1989).

No information was available on the effect of organic enrichment on *Philine quadripartita*. *Cerianthus lloydii* was found near the centre of sewage sludge dumping groups at ca 10% organic carbon but was more abundant at intermediate nutrient enrichment (Hughes, 1998a). But Borja *et al*. (2000) and Gittenberger & van Loon (2011) both assigned *Cerianthus lloydii* to their Ecological Group I, 'species very sensitive to organic enrichment and present under unpolluted conditions (initial state)' in of the AZTI Marine Biotic Index (AMBI) index to assess disturbance (including organic enrichment). The basis for their assessment and relation to the pressure benchmark is not clear.

Sensitivity assessment. Sublittoral muds may be expected to be high in organic nutrients, and the presence of *Virgularia mirabilis* in areas of up to 4.5% organic carbon (Atkinson, 1989) suggest a resistance to organic enrichment at the benchmark level. Therefore, a precautionary resistance of **Medium** is suggested but with Low confidence, and as resilience is probably **Low**, a sensitivity of **Medium** is recorded.

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.

	Resistance	Resilience	Sensitivity
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 sedimentary substrata were replaced with rock substrata the biotope would be lost, as it would no longer be a sedimentary habitat and would no longer support sea pens and burrowing megafauna.

Sensitivity assessment. Resistance to the pressure is considered '**None**', and resilience '**Very low**' or 'None' (as the pressure represents a permanent change) and the sensitivity of this biotope is assessed as '**High'**.

	Resistance	Resilience	Sensitivity
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

Virgularia mirabilis occurs in a number of biotopes, on substrata ranging from mud, sandy mud, and gravelly mud, with or with shell fragments or stones (Connor *et al*., 2004). Greathead *et al.* (2007) suggested that the muscular peduncle of *Virgularia mirabilis* allowed it to occupy coarser muds than the other sea pens, and explained its presence in the Moray Firth and Firth of Forth, and its wider distribution in Scotland. Greathead *et al.* (2007) noted that *Pennatula phosphorea* was absent in the North Minch while *Funiculina quadrangularis* and *Virgularia mirabilis* were present, but that *Pennatula phosphorea* was abundant in soft, adhesive mud with high silt-clay content in Loch

Broom. This may suggest a preference for fine muds. The MNCR only recorded *Pennatula phosphorea* from biotopes in 'mud'. Greathead *et al.* (2007) also noted that *Funiculina quadrangularis* had the most restricted distribution, probably due to a preference of depth and soft deep muds of sheltered loch basins, where it was abundant. Again, the MNCR only recorded *Funiculina quadrangularis* from biotopes in 'mud'. However, it was also recorded from areas of muddy sand in the South and North Minches and in the Fladen Grounds but in deep water. In addition, a 'mud' subtratum was the most important factor in a habitat suitability index model for sea pens developed by Greathead *et al.* (2015). In their model, habitat suitability for *Funiculina quadrangularis* increased with mud content up to a maximum at 90-100% mud. *Pennatula phosphorea* and *Virgularia mirabilis* also had their maximum habitat suitability at 100% mud. All three species had zero habitat suitability at 0% mud. However, gravel content was also important. *Virgularia mirabilis* was the most tolerant of gravel content and was still recorded at 50% gravel while the were no records of *Pennatula phosporea* and *Funiculina quadrangularis* above 40% and 30% gravel respectively (Greathead *et al.*, 2015).

Cerianthus lloydii is recorded from biotopes in muddy to mixed or coarse sediments (Connor *et al*., 1997b). Therefore, it is likely to tolerate changes in sediment type. *Philine quadripartita* is recorded from mud, muddy sand and sand (Thompson, 1976; Connor *et al*., 1997b).

Sensitivity assessment. While the important characteristic species are recorded from a range of sediment types, this biotope (IFiMU.PhiVir) is defined by its occurrence in mud. Therefore, a change in sediment type by one Folk class (see Long, 2006), e.g. from mud to sandy mud and sand would result in loss of the biotope. Therefore, a resistance of **None** is recorded. As the change is permanent, resilience is **Very low** and sensitivity is assessed as **High**.

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

Benthic trawls (e.g. rock hopper ground gear, otter trawls) will remove and capture sea pens (Tuck *et al*., 1998; Kenchington *et al*., 2011), albeit with limited efficiency. Nevertheless, dredging and suction dredging penetrates to greater depth and are likely to remove sea pens. Although *Virgularia mirabilis* will not be able to avoid activities that penetrate into the sediment. Assuming their burrows are only deep enough to hold the entire animal (see Greathead *et al*., 2007), then *Virgularia mirabilis* burrows are up to 40 cm deep.

Cerianthus lloydii can also withdraw into the sediment, and its burrow is up to 40 cm deep. However, *Philine quadripartita* feeds at the surface and burrows to find prey (Thompson, 1976).

Sensitivity assessment. Extraction of sediment to 30 cm (the benchmark) could remove most of the resident sea pens present, the burrowing sea anemones, mobile epifauna, and *Philine quadripartita* from the affected area. Hence, the resistance is probably **None**. Resilience is probably **Low**, resulting in a sensitivity of **High**.

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

Stable sedimentary habitats, such as mud were amongst the most vulnerable to fishing activities, e.g. otterboard trawling (Ball *et al.*, 2000b; Collie *et al.*, 2000). Tracks left by otterboards were visible 18 months after experimental trawls in Gareloch (Ball *et al.*, 2000b). Ball *et al.*, (2000b) concluded that trawling modified the benthic community due to an increase in opportunistic polychaetes. However, Kaiser *et al.* (2006) concluded that otterboards had a significant initial effect on muddy sands and muds, but that the effects were short-lived in mud habitats.

In experimental studies (Kinnear *et al.* 1996; Eno *et al.* 2001) sea pens were found to be largely resilient to smothering, dragging or uprooting by creels or pots. *Virgularia mirabilis* withdrew very quickly into the sediment when exposed to pots or creels so that it was difficult to determine their response. However, all sea pens recovered from being dragged over by pots or creels within 24-72 h, with exception of one individual *Funiculina quadrangularis*.

In *Virgularia mirabilis* withdrawal from physical stimulus is rapid (ca 30 seconds) (Hoare & Wilson, 1977; Ambroso *et al.*, 2013). Birkland (1974) maintained that the only way to capture all of the sea pens in an area (quadrat) was to remove them slowly by hand until no more emerged. But several studies note that their ability to withdraw into the sediment in response to bottom towed or dropped gear (e.g. creels, pots, camera/video mounted towed sleds, experimental grab, trawl, or dredge) means that sea pen abundance can be difficult to estimate (Birkeland, 1974; Eno *et al.*, 2001; Greathead *et al.*, 2007; Greathead *et al.*, 2011). The ability to withdraw also suggests that sea pens can avoid approaching demersal trawls and fishing gear. This was suggested as the explanation for the similarity in the densities of *Virgularia mirabilis* in trawled and untrawled sites in Loch Fyne, and the lack of change in sea pen density observed after experimental trawling (using modified rock hopper ground gear) over a 18 month period in Loch Gareloch (Howson & Davies 1991; Hughes 1998a; Tuck *et al.* 1998). Kenchington *et al.* (2011) estimated the gear efficiency of otter trawls for sea pens (*Anthoptilum* and *Pennatula*) to be in the range of 3.7 – 8.2%, based on estimates of sea pen biomass from (non-destructive) towed camera surveys. However, species obtained by dredges were invariably damaged (Hoare & Wilson, 1977). Hoare & Wilson (1977) noted that *Virgularia* was absent for areas of Holyhead Harbour disturbed by dragging or boat mooring, although no causal evidence was given (Hughes, 1998a). Sea pens are potentially vulnerable to long lining. Munoz *et al.* (2011) noted that small numbers of Pennatulids (inc. *Pennatula* sp.) were retrieved from experimental long-lining around the Hatton Bank in the north east Atlantic, presumably either attached to hooks or wrapped in line as it passed across the sediment. Hixon & Tissot (2007) noted that sea pens (*Stylatula* sp.) were four times more abundant in untrawled areas relative to trawled areas in the Coquille Bank, Oregon, although no causal relationship was shown.

No information on the effects of abrasion or penetrative gear on *Cerianthus lloydii* or *Philine quadripartita* was found. Greathead *et al.* (2011) was not able to conclude if the variation in *Cerianthus* abundance in the Fladden Grounds was due to miscounting, its patchy distribution or fishing activity.

Sensitivity assessment. The reviews by Ball *et al.* (2000), Collie *et al.* (2000) and Kasier *et al.* (2006) suggest that stable sediments, e.g. muds are likely to be vulnerable to fishing activities. The evidence for *Virgularia mirabilis* suggests that its ability to withdraw into the sediment quickly would avoid surface abrasion from creels and pots but that dragging and mooring lines may be damaging, and individuals may be caught and removed by fishing lines (e.g. long-lines). *Philine quadripartita* feeds at the surface and burrows to find prey (Thompson, 1976) so that it might be susceptible to damage from passing gear or moorings. Therefore, a resistance of **Medium** is recorded due to the potential disturbance to the biotope as a whole. As the impact may be limited (see Kenchington *et al.*, 2011), a resilience of **Medium** is suggested and sensitivity is assessed as

Medium.

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

Stable sedimentary habitats, such as mud were amongst the most vulnerable to fishing activities, e.g. otter trawling (Ball *et al*., 2000; Collie *et al*., 2000). Tracks left by otter were visible 18 months after experimental trawls in Gareloch (Ball *et al*., 2000). Ball *et al*., (2000) concluded that trawling modified the benthic community due to an increase in opportunistic polychaetes. However, Kaiser *et al.* (2006) concluded that otter trawls had a significant initial effect on muddy sands and muds, but that the effects were short-lived in mud habitats.

In *Virgularia mirabilis* withdrawal from the physical stimulus is rapid (ca 30 seconds) (Hoare & Wilson, 1977; Ambroso *et al*., 2013). Birkland (1974) maintained that the only way to capture all of the sea pens in an area (quadrat) was to remove them slowly by hand until no more emerged. But several studies note that their ability to withdraw into the sediment in response to bottom towed or dropped gear (e.g. creels, pots, camera/video mounted towed sleds, experimental grab, trawl, or dredge) means that sea pen abundance can be difficult to estimate (Birkeland, 1974; Eno *et al*., 2001; Greathead *et al*., 2007; Greathead *et al*., 2011). The ability to withdraw also suggests that sea pens can avoid approaching demersal trawls and fishing gear. This was suggested as the explanation for the similarity in the densities of *Virgularia mirabilis* in trawled and untrawled sites in Loch Fyne, and the lack of change in sea pen density observed after experimental trawling (using modified rock hopper ground gear) over a 18 month period in Loch Gareloch (Howson & Davies 1991; Hughes 1998a; Tuck *et al.* 1998). Kenchington *et al.* (2011) estimated the gear efficiency of otter trawls for sea pens (*Anthoptilum* and *Pennatula*) to be in the range of 3.7 – 8.2%, based on estimates of sea pen biomass from (non-destructive) towed camera surveys. However, species obtained by dredges were invariably damaged (Hoare & Wilson, 1977). Hoare & Wilson (1977) noted that *Virgularia* was absent for areas of Holyhead Harbour disturbed by dragging or boat mooring, although no causal evidence was given (Hughes, 1998a). Sea pens are potentially vulnerable to long lining. Munoz *et al.* (2011) noted that small numbers of Pennatulids (inc. *Pennatula* sp.) were retrieved from experimental long-lining around the Hatton Bank in the north east Atlantic, presumably either attached to hooks or wrapped in line as it passed across the sediment. Hixon & Tissot (2007) noted that sea pens (*Stylatula* sp.) were four times more abundant in untrawled areas relative to trawled areas in the Coquille Bank, Oregon, although no causal relationship was shown.

No information on the effects of abrasion or penetrative gear on *Cerianthus lloydii* or *Philine quadripartita* was found. Greathead *et al.* (2011) were not able to conclude if the variation in *Cerianthus* abundance in the Fladden Grounds was due to miscounting, its patchy distribution or fishing activity.

Sensitivity assessment. The reviews by Ball *et al.* (2000), Collie *et al.* (2000) and Kasier *et al.* (2006) suggest that stable sediments, e.g. muds are likely to be vulnerable to fishing activities. The evidence for *Virgularia mirabilis* suggests that its ability to withdraw into the sediment quickly would avoid surface abrasion from creels and pots but that dragging and mooring lines may be damaging, individuals may be caught and removed by fishing lines (e.g. long-lines), and penetrative gear is likely to remove a proportion of the population. *Philine quadripartita* feeds at the surface and burrows to find prey (Thompson, 1976) so that it might be susceptible to damage from passing gear or moorings. Therefore, a resistance of **Medium** is recorded due to the potential disturbance to the biotope as a whole. The resilience is probably **Low** so that sensitivity is assessed as **Medium**.

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

The sea pen species assessed live in sheltered areas, in fine sediments, subject to high suspended sediment loads. The effect of increased deposition of fine silt is uncertain but it is possible that feeding structures may become clogged. When tested, *Virgularia mirabilis* quickly seized and rejected inert particles (Hoare & Wilson, 1977). Hiscock (1983) observed *Virgularia mirabilis* secretes copious amounts of mucus which could keep the polyps clear of silt. Kinnear *et al.* (1996) noted that another species of sea pen, *Funiculina quadrangularis*, was quick to remove any adhering mud particles by the production of copious quantities of mucus. *Virgularia mirabilis* is also likely to be able to self-clean (Hiscock, 1983). No indication of the suspended sediment load was given in any evidence found. An increase in suspended sediment is unlikely to interfere with feeding in either *Cerianthus lloydii* or *Philine quadripartita*. *Cerianthus lloydii* is a passive predator while *Philine quadripartita* is an active predator that ploughs through the surface of the substratum looking for prey. Other members of the infaunal community are deposit feeders, predators or omnivores and unlikely to be affected. However, an increase in turbidity and increased ,light attenuation may reduce the prevalence of microphytobenthos diatoms.

If sea pen feeding is reduced by increases in suspended sediment the viability of the population will be reduced. Once siltation levels return to normal, feeding will be resumed therefore recovery will be rapid. Overall, resistance is probably **High,** hence, resilience is also **'High,** and the biotope is probably **Not sensitive** at the benchmark level.

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

Natural accretion rates are potentially high in the sheltered muddy habitats. Hiscock (1983) observed *Virgularia mirabilis* secretes copious amounts of mucus, which could keep the polyps clear of silt and is also likely to be able to self-clean. Kinnear *et al.* (1996) noted that *Funiculina quadrangularis* was quick to remove any adhering mud particles by the production of copious quantities of mucus, once the source of smothering (in this case potting) was removed. *Virgularia mirabilis* can burrow and move into and out of their own burrows. It is probable therefore that deposition of 5 cm of fine sediment will have little effect other than to temporarily suspend feeding and the energetic cost of burrowing.

In normal accretion, *Cerianthus lloydii* keeps pace with the accretion and, as a result, develops burrows much larger than the animal itself (Schäfer, 1972; Bromley, 2012). Schäfer (1972) reported that an increase in depositional rate led to an avoidance behaviour in *Cerianthus lloydii*. The organism ceases tube building activity and instead the animal bunches its tentacles and intrudes its way up to the new surface, where it establishes a new burrow. However, no information on the depth of material through which is can burrow was given.

Philine quadripartita ploughs through the surface of the substratum and creates furrows in its wake. Thompson (1976) suggested that it only burrowed into the substratum in pursuit of prey.

Sensitivity assessment. The deposition of 5 cm of fine sediment is unlikely to affect the community adversely. Both *Virgularia* and *Cerianthus* can withdraw into their tube and can probably re-emerge through 5 cm of fines. *Philine aperta* is a large opisthobranch (up to 7 cm in length) that could probably move through a deposit of only 5 cm. The remaining infauna of polychaetes and bivalves are adapted to accreting environments and may be unaffected. However, no direct evidence was found. Therefore, a resistance of **High** is suggested, resulting in a resilience of **High**, so that the biotope is probably **'Not sensitive'** at the benchmark level.

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

Natural accretion rates are potentially high in the sheltered muddy habitats. Hiscock (1983) observed *Virgularia mirabilis* secretes copious amounts of mucus, which could keep the polyps clear of silt and is also likely to be able to self-clean. Kinnear *et al.* (1996) noted that *Funiculina quadrangularis* was quick to remove any adhering mud particles by the production of copious quantities of mucus, once the source of smothering (in this case potting) was removed. *Virgularia mirabilis* can burrow and move into and out of their own burrows. It is probable therefore that deposition of 5 cm of fine sediment will have little effect other than to temporarily suspend feeding and the energetic cost of burrowing.

In normal accretion, *Cerianthus lloydii* keeps pace with the accretion and, as a result, develops burrows much larger than the animal itself (Schäfer, 1972; Bromley, 2012). Schäfer (1972) reported that an increase in depositional rate led to an avoidance behaviour in *Cerianthus lloydii*. The organism ceases tube building activity and instead the animal bunches its tentacles and intrudes its way up to the new surface, where it establishes a new burrow. However, no information on the depth of material through which is can burrow was given.

Philine quadripartita ploughs through the surface of the substratum and creates furrows in its wake. Thompson (1976) suggested that it only burrowed into the substratum in pursuit of prey.

Sensitivity assessment. The deposition of 30 cm of fine sediment is may affect the community adversely. *Virgularia mirabilis* and *Cerianthus lloydii* can burrow and move into and out of their own burrows, which can be up to 40 cm deep. It is probable, therefore, that deposition of 30 cm of fine sediment will have little effect other than to suspend feeding temporarily and the energetic cost of burrowing. However, *Philine aperta* lives primarily at the surface of the sediment, so that a sudden deposit of 30 cm of fine sediment may result in mortality of the opisthobranch, However, no direct evidence was found. Therefore, a resistance of **Low** is suggested due to the potential mortality of *Philine aperta* but with Low confidence. The resilience is probably **High** based on the recovery of *Philine quadripartita* population so that the biotope is probably **Low** 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	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence was found

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

Some of the characterizing species associated with this biotope, in particular, the sea pens, may respond to sound vibrations and can withdraw into the sediment. Feeding will resume once the disturbing factor has passed. However, most of the species are infaunal and unlikely respond to noise disturbance at the benchmark level. Therefore, this pressure is probably **Not relevant** in this biotope.

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

Shallow examples of this biotope develop a cover of microphytobenthic diatoms. so as increase in incident light may encourage their growth, while shading will inhibit their growth. Nevertheless, this biotope is dominated by deposit feeders and predators, so that the majority of the productivity is secondary. Therefore, the biotope is probably **Not sensitive** (resistance and resilience are **High**).

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–this pressure is considered applicable to mobile species, e.g. fish and marine mammals rather than seabed habitats. Physical and hydrographic barriers may limit the dispersal of seed. But seed dispersal is not considered under the pressure definition and benchmark.

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

Most species within the biotope are burrowing and have no or poor visual perception and are unlikely to be affected by visual disturbance such as shading. Epifauna such as crabs have well developed visual acuity and are likely to respond to movement in order to avoid predators. However, it is unlikely that the species will be affected by visual disturbance at the benchmark level.

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	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

No evidence of genetic modification, breeding, or translocation was found.

Introduction or spread of invasive non-indigenous species	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

In southern Britain, *Sternapsis scutata* is characterstic of this biotope (Connor *et al*., 2004). *Sternapsis scutata* is a non-native polychaete that has extended its range in inshore muddy sediments in the south west of the UK (Shelley *et al*., 2008). However, in mesocosm experiments, little effect on biological functioning was detected after the introduction of the polychaete and a doubling of its biomass (Shelley *et al*., 2008). No direct evidence on the effect of non-native species on mud communities was found. However, this assessment should be revisited in the light of new evidence.

Introduction of microbial pathogens	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

No evidence was available on the effect of microbial pathogens on *Cerianthus lloydii* or *Philine quadripartita* or sea pens.

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

None of the characterizing species within this biotope are currently directly targeted in the UK and hence this pressure is considered to be 'Not relevant'.

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

The physical effects of fisheries or dredging activities are addressed under abrasion, penetration and extraction pressures above. No clear biological relationships between the important characteristic species were found. Therefore, removal of any one species may not affect other members of the community adversely. However, is the important characterizing species were removed as by-catch, the character of the biotope would change. A significant decline in the abundance of either *Philine quadripartita* or *Virgularia mirabilis* would result in loss of the biotope as recognised by the habitat classification. Therefore, a resistance of **Medium** is recorded, albeit at Low confidence. As resilience is probably **Low**, sensitivity is assessed as **Medium**.

Bibliography

Ambroso, S., Dominguez-Carrió, C., Grinyó, J., López-González, P., Gili, J.-M., Purroy, A., Requena, S. & Madurell, T., 2013. *In situ* observations on withdrawal behaviour of the sea pen *Virgularia mirabilis*. *Marine Biodiversity*, **43** (4), 257-258.

Ball, B., Munday, B. & Tuck, I., 2000b. Effects of otter trawling on the benthos and environment in muddy sediments. In: *Effects of fishing on non-target species and habitats*, (eds. Kaiser, M.J. & de Groot, S.J.), pp 69-82. Oxford: Blackwell Science.

Birkeland, C., 1974. Interactions between a seapen and seven of its predators. *Ecological Monographs*, **44**, 211-232.

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.

Bromley, R.G., 2012. *Trace Fossils: Biology, Taxonomy and Applications:* Routledge.

Chia, F.S. & Crawford, B.J., 1973. Some observations on gametogenesis, larval development and substratum selection of the sea pen *Ptilosarcus guerneyi*. *Marine Biology*, **23**, 73-82.

Collie, J.S., Hall, S.J., Kaiser, M.J. & Poiner, I.R., 2000. A quantitative analysis of fishing impacts on shelf-sea benthos. *Journal of Animal Ecology*, **69** (5), 785–798.

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.

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

Dauwe, B., Herman, P.M.J. & Heip, C.H.R., 1998. Community structure and bioturbation potential of macrofauna at four North Sea stations with contrasting food supply. *Marine Ecology Progress Series*, **173**, 67-83.

Diaz, R.J. & Rosenberg, R., 1995. Marine benthic hypoxia: a review of its ecological effects and the behavioural responses of benthic macrofauna. *Oceanography and Marine Biology: an Annual Review*, **33**, 245-303.

Edwards, C.B. & Moore, C.G., 2008. Reproduction in the sea pen *Pennatula phosphorea* (Anthozoa: Pennatulacea) from the west coast of Scotland *Marine Biology* **155**:303–314

Edwards, D.C.B. & Moore, C.G., 2009. Reproduction in the sea pen *Funiculina quadrangularis* (Anthozoa: Pennatulacea) from the west coast of Scotland. *Estuarine, Coastal and Shelf Science*, **82**, 161-168.

Eno, N.C., MacDonald, D.S., Kinnear, J.A.M., Amos, C.S., Chapman, C.J., Clark, R.A., Bunker, F.S.P.D. & Munro, C., 2001. Effects of crustacean traps on benthic fauna *ICES Journal of Marine Science*, **58**, 11-20.

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

Greathead, C., Demain, D., Dobby, H., Allan, L. & Weetman, A., 2011. *Quantitative assessment of the distribution and abundance of the burrowing megafauna and large epifauna community in the Fladen fishing ground, northern North Sea.* Scottish Government: Edinburgh (UK).

Greathead, C., González-Irusta, J.M., Clarke, J., Boulcott, P., Blackadder, L., Weetman, A. & Wright, P.J., 2015. Environmental requirements for three sea pen species: relevance to distribution and conservation. *ICES Journal of Marine Science: Journal du Conseil*, **72** (2), 576-586.

Greathead, C.F., Donnan, D.W., Mair, J.M. & Saunders, G.R., 2007. The sea pens *Virgularia mirabilis, Pennatula phosphorea* and *Funiculina quadrangularis*: distribution and conservation issues in Scottish waters. *Journal of the Marine Biological Association*, **87**, 1095-1103.

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

Hansen, B. & Ockelmann, K.W., 1991. Feeding behaviour in larvae of the opisthobranch *Philine aperta*. I. Growth and functional response at the different developmental stages. *Marine Biology*, **111**, 255-261.

Hansen, B., 1991. Feeding behaviour in larvae of the opisthobranch *Philine aperta*. II. Food size spectra and particle selectivity in relation to larval behaviour and morphology of the velar structures. *Marine Biology*, **111**, 263-270.

Hill, J.M. & Wilson, E., 2000. *Virgularia mirabilis*. Slender sea pen. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. , Plymouth: Marine Biological Association of the United Kingdom. (20/02/14). http://www.marlin.ac.uk/speciesbenchmarks.php?speciesID=4579

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

Hixon, M.A. & Tissot, B.N., 2007. Comparison of trawled vs untrawled mud seafloor assemblages of fishes and macroinvertebrates at Coquille Bank, Oregon. *Journal of Experimental Marine Biology and Ecology*, **344** (1), 23-34.

Hoare, R. & Wilson, E.H., 1977. Observations on the behaviour and distribution of *Virgularia mirabilis* O.F. Müller (Coelenterata: Pennatulacea) in Holyhead harbour. In *Proceedings of the Eleventh European Symposium on Marine Biology, University College, Galway, 5-11 October 1976. Biology of Benthic Organisms*, (ed. B.F. Keegan, P.O. Ceidigh & P.J.S. Boaden, pp. 329-337. Oxford: Pergamon

Press. Oxford: Pergamon Press.

Howson, C.M. & Davies, L.M., 1991. Marine Nature Conservation Review, Surveys of Scottish Sea Lochs. A towed video survey of Loch Fyne. Vol. 1 - Report. *Report to the Nature Conservancy Council from the University Marine Biological Station, Millport.*

Howson, C.M., Connor, D.W. & Holt, R.H.F., 1994. The Scottish sealochs - an account of surveys undertaken for the Marine Nature Conservation Review. *Joint Nature Conservation Committee Report*, No. 164 (Marine Nature Conservation Review Report MNCR/SR/27)., Joint Nature Conservation Committee Report, No. 164 (Marine Nature Conservation Review Report MNCR/SR/27).

Hughes, D.J., 1998a. Sea pens & burrowing megafauna (volume III). An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. *Natura 2000 report prepared for Scottish Association of Marine Science (SAMS) for the UK Marine SACs Project.*, Scottish Association for Marine Science. (UK Marine SACs Project). Available from: http://www.ukmarinesac.org.uk/publications.htm

Hughes, D.J., 1998b. Subtidal brittlestar beds. An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. *Natura 2000 report prepared for Scottish Association of Marine Science (SAMS) for the UK Marine SACs Project.*, Scottish Association for Marine Science. (UK Marine SACs Project, Vol. 3). Available from: http://www.ukmarinesac.org.uk/pdfs/britstar.pdf

Jones, L.A., Hiscock, K. & Connor, D.W., 2000. Marine habitat reviews. A summary of ecological requirements and sensitivity characteristics for the conservation and management of marine SACs. *Joint Nature Conservation Committee, Peterborough. (UK Marine SACs Project report.).* Available from: http://www.ukmarinesac.org.uk/pdfs/marine-habitats-review.pdf

Kaiser, M., Clarke, K., Hinz, H., Austen, M., Somerfield, P. & Karakassis, I., 2006. Global analysis of response and recovery of benthic biota to fishing. *Marine Ecology Progress Series*, **311**, 1-14.

Kenchington, E., Murillo, F.J., Cogswell, A. & Lirette, C., 2011. Development of Encounter Protocols and Assessment of Significant Adverse Impact by Bottom Trawling for Sponge Grounds and Sea Pen Fields in the NAFO Regulatory Area. NAFO, Dartmouth, NS, Canada, 51 pp. http://search.proquest.com/docview/1020851501?accountid=28412 http://archive.nafo.int/open/sc/2011/scr11-075.pdf

Kinnear, J.A.M., Barkel, P.J., Mojseiwicz, W.R., Chapman, C.J., Holbrow, A.J., Barnes, C. & Greathead, C.F.F., 1996. Effects of *Nephrops* creels on the environment. *Fisheries Research Services Report No. 2/96.*

Lancaster, S.M., 1983. The biology and reproductive ecology of *Philine aperta* (Opisthobranchia: Bullomorpha) in Oxwich Bay. *Journal of Molluscan Studies*, Suppl. **12A**, 82-88.

MES, 2010. *Marine Macrofauna Genus Trait Handbook*. Marine Ecological Surveys Limited. http://www.genustraithandbook.org.uk/

Moore, P.G. & Cameron, K.S., 1999. A note on a hitherto unreported association between *Photis longicaudata* (Crustacea: Amphipoda) and *Cerianthus lloydii* (Anthozoa: Hexacorallia). *Journal of the Marine Biological Association of the United Kingdom*, **79**, 369-370.

Munoz, D.P., Murillo, F.J., Sayago-Gil, M., Serrano, A., Laporta, M., Otero, I. & Gomez, C., 2011. Effects of deep-sea bottom longlining on the Hatton Bank fish communities and benthic ecosystem, north-east Atlantic. *Journal of the Marine Biological Association of the United Kingdom*, **91** (4), 939-952.

Nilsson, H.C. & Rosenberg, R., 1994. Hypoxic response of two marine benthic communities. *Marine Ecology Progress Series*, **115**, 209-217.

Price, R.M., Gosliner, T.M. & Valdes, A., 2011. Systematics and phylogeny of *Philine* (Gastropoda: Opisthobranchia), with emphasis on the *Philine aperta* species complex. *Veliger*, **51** (2), 1-58.

Roberts, D.A., Johnston, E.L. & Knott, N.A., 2010b. Impacts of desalination plant discharges on the marine environment: A critical review of published studies. *Water Research*, **44** (18), 5117-5128.

Rosenberg, R., 1995. Benthic marine fauna structured by hydrodynamic processes and food availability. *Netherlands Journal of Sea Research*, **34**, 303-317.

Rowden, A.A., Jago, C.F. & Jones, S.E., 1998b. Influence of benthic macrofauna on the geotechnical and geophysical properties of surficial sediment, North Sea. *Continental Shelf Research*, **18**, 1347-1363.

Ruso, Y.D.P., la Ossa Carretero, J.A.D., Casalduero, F.G. & Lizaso, J.L.S., 2007. Spatial and temporal changes in infaunal communities inhabiting soft-bottoms affected by brine discharge. *Marine environmental research*, **64** (4), 492-503.

Schäfer, H., 1972. *Ecology and palaeoecology of marine environments*, 568 pp. Chicago: University of Chicago Press.

Shelley, R., Widdicombe, S., Woodward, M., Stevens, T., McNeill, C.L. & Kendall, M.A. 2008. An investigation of the impacts on biodiversity and ecosystem functioning of soft sediments by the non-native polychaete *Sternaspis scutata* (Polychaeta: Sternaspidae). *Journal of Experimental Marine Biology and Ecology*, **366**, 146-150.

Soong, K., 2005. Reproduction and colony integration of the sea pen *Virgularia juncea. Marine Biology*, **146** (6), 1103-1109.

Stachowitsch, M., 1992b. Benthic communities: eutrophication's memory mode. In *The Response of marine transitional systems to human impact: problems and perspectives for restoration* Proceedings of an International Conferencee, Bologna, Italy, 21-24 March, 1990, (ed. R.A. Vollenweider, R. Marchetti, & R. Viviani), pp.1017-1028. Amsterdam: Elsevier.

Thompson, T.E., 1976. *Biology of Opisthobranch Molluscs*, vol. 1. London: The Ray Society.

Thompson, T.E., 1988. *Molluscs: Benthic Opisthobranchs.* London: Bath Press. [Synopses of the British Fauna New Series), (ed. Doris M. Kermack & R.S.K. Barnes), no. 8 (second Edition)].

Tillin, H. & Tyler-Walters, H., 2014. Assessing the sensitivity of subtidal sedimentary habitats to pressures associated with marine activities. Phase 2 Report – Literature review and sensitivity assessments for ecological groups for circalittoral and offshore Level 5 biotopes. *JNCC Report* No. 512B, 260 pp. Available from: www.marlin.ac.uk/publications

Tuck, I.D., Hall, S.J., Robertson, M.R., Armstrong, E. & Basford, D.J., 1998. Effects of physical trawling disturbance in a previously unfished sheltered Scottish sea loch. *Marine Ecology Progress Series*, **162**, 227-242.

Wilson, M.T., Andrews, A.H., Brown, A.L. & Cordes, E.E., 2002. Axial rod growth and age estimation of the sea pen, *Halipteris willemoesi* Kölliker *Hydrobiologia*, **471**, 133-142.

Wright, J., Colling, A., Park, D. & Open University Oceanography Course Team, 2001. *Waves, Tides, and Shallow-water Processes*. Oxford: Butterworth-Heinemann.