MarLIN
Marine Information Network
Information on the species and habitats around the coasts and sea of the British Isles

Virgularia mirabilis and *Ophiura* spp. with *Pecten maximus*, hydroids and ascidians on circalittoral sandy or shelly mud with stones

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

Jacqueline Hill & Dr Harvey Tyler-Walters

2018-03-20

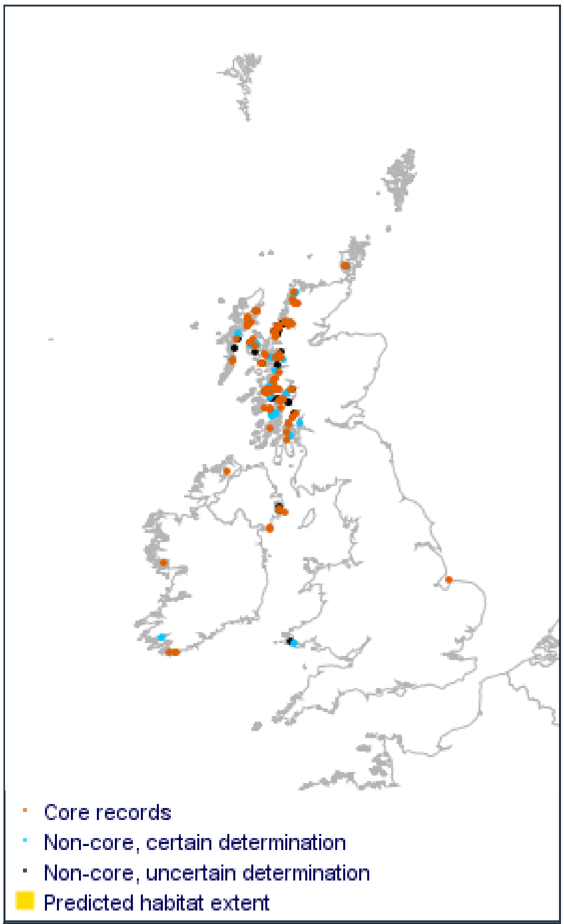
A report from:
The Marine Life Information Network, Marine Biological Association of the United Kingdom.

Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [https://www.marlin.ac.uk/habitats/detail/147]. All terms and the MarESA methodology are outlined on the website (https://www.marlin.ac.uk)

This review can be cited as:
Hill, J.M. & Tyler-Walters, H. 2018. [Virgularia mirabilis] and [Ophiura] spp. with [Pecten maximus], hydroids and ascidians on circalittoral sandy or shelly mud with stones. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom.
DOI https://dx.doi.org/10.17031/marlinhab.147.1

The information (TEXT ONLY) provided by the Marine Life Information Network (MarLIN) is licensed under a Creative Commons Attribution-Non-Commercial-Share Alike 2.0 UK: England & Wales License. Note that images and other media featured on this page are each governed by their own terms and conditions and they may or may not be available for reuse. Permissions beyond the scope of this license are available here. Based on a work at www.marlin.ac.uk

(page left blank)



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

Researched by Jacqueline Hill & Dr Harvey Tyler-Walters **Refereed by** This information is not refereed.

Summary

UK and Ireland classification

EUNIS 2008	A5.3541	*Virgularia mirabilis* and *Ophiura* spp. with *Pecten maximus*, hydroids and ascidians on circalittoral sandy or shelly mud with shells or stones
JNCC 2015	SS.SMu.CSaMu.VirOphPmax.HAs	*Virgularia mirabilis* and *Ophiura* spp. with *Pecten maximus*, hydroids and ascidians on circalittoral sandy or shelly mud with stones
JNCC 2004	SS.SMu.CSaMu.VirOphPmax.HAs	*Virgularia mirabilis* and *Ophiura spp.* with *Pecten maximus*, hydroids and ascidians on circalittoral sandy or shelly mud with stones
1997 Biotope	SS.CMS._.VirOph.HAs	*Virgularia mirabilis* and *Ophiura spp.* with hydroids and ascidians on circalittoral sandy or shelly mud with shells or stones

Description

Circalittoral fine sandy mud with shell gravel and notable quantities of shells or small stones scattered over the sediment surface. These sediments, like SMU.VirOphPmax, may contain *Virgularia mirabilis*, *Pecten maximus* and *Ophiura* spp. but shells and small stones scattered over the sediment surface provided sufficient stable substrata for a variety of sessile epifaunal species to occur. Of these, the hydroids *Kirchenpaueria pinnata*, *Nemertesia antennina* and *Nemertesia ramosa* are most common with solitary ascidians such as *Corella parallelogramma* and *Ascidia mentula* also present. The anemone *Cerianthus lloydii* is often found in the sediment together with occasional Lanice conchilega. The serpulids *Protula tubularia*, *Serpula vermicularis* and *Spirobranchus triqueter* and the barnacles *Balanus balanus* and *Balanus crenatus* are also often present on pebbles and shells. *Munida rugosa* are occasionally found under larger stones. All these species are typical of more rocky habitats in such sheltered conditions. As with SMU.VirOphPmax this biotope is primarily identified on the basis of its epifauna and may be an epibiotic overlay over other closely related biotopes such as AfilMysAnit and AfilNten. (Information from Connor *et al*., 2004; JNCC, 2015).

Depth range

5-10 m, 10-20 m, 20-30 m, 30-50 m

Additional information

-

Listed By

- none -

Further information sources

Search on:

G G JNCC

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

Virgularia mirabilis and *Ophiura* spp. are the main important characterizing species, giving the name to the biotope (SS.SMu.CSaMu.VirOphPmax). *Cerianthus lloydii* is another characteristic member of the epifauna found in the majority of records. *Pecten maximus* can occur in small numbers but is found in the majority of records of the biotope. Connor *et al.* (2004) suggested that this biotope represented an epifaunal overlay of other similar sedimentary biotopes such as (e.g. CSaMU.AfilMysAnit or CSaMu.AfilNten, so that members of the infauna are probably found in a range of other biotopes in similar sediments. *Amphiura* spp. may be present but reaches higher abundance in SMU.CFiMu.SpnMeg or CSaMU.AfilMysAnit. The other characterizing species are mobile (e.g. crabs and hermit crabs) and are not restricted to this biotope.

Therefore, the assessment of sensitivity is based on the dominant epifauna, sandy or gravelly mud habitat, the important characterizing species *Virgularia mirabilis*, *Ophiura* spp., and the characteristic *Cerianthus lloydii*, *Pecten maximus*, hydroids and ascidians where relevant. The sensitivity of other species is also discussed where relevant.

The sub-biotope CSaMu.VirOphPmax.HAs includes a diverse epifauna of hydroids and ascidians due to the presence of small stones, pebbles, and shell on the surface of the sediment. The sensitivity of the CSaMu.VirOphPmax and its sub-biotope CSaMu.VirOphPmax.HAs are likely to be similar. Any differences in the response to individual pressures between the biotope and its sub-biotope are highlighted in the text.

Resilience and recovery rates of habitat

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). In addition, 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 & Wilson, 1977). *Virgularia mirabilis* was found to withdraw into its burrow rapidly (ca 30 seconds) and could not be uprooted by dragged creels (Hoare & 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).

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 its 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).

Ophiura spp. are found in sandy, high-energy environments where the sediment is subject to natural disturbance. These species have life history traits associated with opportunistic species with short generation times, rapid reproduction, and high dispersal potential. Tyler (1977a) found that populations of *Ophiura albida* in the Bristol Channel had a well-marked annual reproductive cycle, with spawning taking place in May and early June. Spent adults and planktonic larvae were found up to early October. This short annual reproductive period led to the occurrence of distinct size cohorts in the adult population. Dahm (1993) determined a maximum age of 9 years at a disk diameter of 9 mm for specimens from German Bight while Künitzer (cited in Dahm, 1993) suggested a lifespan of up to 10 years in the North Sea. In contrast, the larger *Ophiura ophiura* had a more protracted breeding season, and adult size classes were less distinct (Tyler, 1977a). *Ophiura ophiura* is reproductively dormant during summer, with oocytes carried overwinter (Tyler, 1977a). Ophiopluteus larvae occur between March and October but year round spawning is unlikely and, like other brittlestar species, oocytes are laid down at the end of the spawning period, lay dormant over winter and develop in the following year (Wood *et al*., 2010). Gage (1990) suggested a lifespan of 5 -6 years for *Ophiura ophiura* from the west of Scotland, which agreed with Mortensen's (1927) estimate for the British Isles. However, analysis of growth rings in specimens from the German Bight suggested a maximum age of 9 yr at a disk diameter of 15.2 mm (Dahm, 1993). Dahm (1993) noted that growth rates and lifespan may vary regionally but that prior studies probably underestimated age and overestimated growth rate. Boos & Franke (2006) found that *Ophuira* sp. were amongst the six most common species of brittlestar in the German Bight (North Sea) and were part of a stable community of brittlestars present for ca 130 years.

Recovery of *Pecten maximus* populations may occur through adult migration over small scales or through recolonization by larvae. *Pecten maximus* can swim for short periods by clapping the valves together. Swimming is limited in terms of distance and endurance and is primarily reserved for escape reactions given the high energy expenditure involved. Tagging experiments in Loch Creran, western Scotland, found that the vast majority of tagged *Pecten maximus* adults were within 30 m of the release point after 18 months (Howell & Fraser, 1984).

Adult scallops, therefore, rely on larval dispersal to ensure geographic distribution of the species (Brand, 1991) and recovery following a decline of the population will rely on larval recruitment.

The timing of spawning may be influenced by both internal and external factors such as genetic adaptation (Ansell *et al.* 1991) age and temperature respectively (Barber & Blake, 1991). In general, mature scallops spawn over the summer months from April or May to September. Dispersal potential in *Pecten maximus* is high given that the length of the pelagic larval stage exceeds one month (Marshall & Wilson, 2009). The generation time for this species is between two and a half and three years.

However, factors including hydrographic features and the survival of larvae will determine the extent to which the larvae are dispersed and, consequently, the scallops have an aggregated distribution within their geographic range. The major fishing grounds for scallops are generally so widely separated that respective environmental conditions produce marked differences in population parameters (Brand, 1991). In addition, Sinclair *et al.* (1985) hypothesized that, by using vertical migrations in the water column, *Pecten maximus* larvae may be able to maintain their location within the confines of the scallop bed. Darby & Durance (1989) considered the *Pecten maximus* populations of Eddystone Bay, Wolf Rock, and Cardigan Bay to be self-recruiting and suggested this to be the reason why the Cardigan Bay population has never fully recovered after being fished out in one year. It is also likely that the population of *Pecten maximus* at Mulroy Bay is self-recruiting (Beaumont, 2005).

Self-recruiting populations are dependent on successful recruitment from within the parent bed. In St Brieuc, France, entire populations of scallops have been shown to spawn within just a few days (Paulet *et al.* 1988). Anything that has the potential to disrupt the success of this mass spawning will adversely affect recruitment to the stock. In addition, *Pecten maximus* is generally thought to have a low population turnover (Rees & Dare, 1993) and scallop stock recruitment is highly variable (Beukers-Stewart *et al.*, 2003). Sinclair *et al.* (1985) stated that if all the scallops are fished out of an area, future recruitment should not be expected from contiguous areas within the time frame of interest to fisheries management and, therefore, some minimum spawning stock must remain in each area to ensure long-term harvesting potential. In the Isle of Man, the larval supply rate is low but constant and the comparatively high and constant recruitment rate of juveniles indicates a very high survival rate when there is a low density of spat present at the end of the settlement season (Beukers-Stewart *et al.*, 2003).

Therefore, providing a certain proportion of the population remains after exploitation, a good spawning episode occurs and suitable environmental conditions prevail after exploitation for the larval, veliger and juvenile stages including a suitable substratum and temperature regime, there is the potential for a strong recruitment and recovery. Under certain environmental conditions, however, recovery could take significantly longer. If none of the population remained and the population was thought to be self-recruiting, the population may never fully recover. Overall, *Pecten maximus* populations have the potential to recover within ca 2-10 years depending on local recruitment.

Hydroids are often the first organisms to colonize available space in settlement experiments (Gili & Hughes, 1995). Few species of hydroids have specific substrata requirements and many are generalists capable of growing on a variety of substrata. Hydroids are also capable of asexual reproduction and many species produce dormant, resting stages that are very resistant of environmental perturbation (Gili & Hughes, 1995). *Nemertesia antennina* releases planulae on mucus threads, that increase potential dispersal to 5 -50m, depending on currents and turbulence (Hughes, 1977). Hughes (1977) noted that only a small percentage of the population of *Nemertesia antennina* in Torbay developed from dormant, regressed hydrorhizae, the majority of the population developing from planulae as three successive generations. Rapid growth, budding and the formation of stolons allow hydroids to colonize space rapidly. Fragmentation may also provide another route for short distance dispersal. Rafting on floating debris (or hitch hiking on ships hulls or in ship ballast water) as dormant stages or reproductive adults, together with their potentially long lifespan, may have allowed hydroids to disperse over a wide area in the long-term and explain the near cosmopolitan distributions of many hydroid species (Cornelius, 1992; Gili & Hughes, 1995).

Ascidia mentula is a larger (up to 18 cm long) and long-lived (up to 7 years). Recruitment was reported to occur year round in Sweden at depths greater than 20 m, with seasonal spawning occurring at 15 m (where sea temperature variability is much greater). Long-term data from populations of the ascidian *Ascidia mentula* on subtidal vertical rock indicated that recruitment of *Ascidia mentula* larvae was positively correlated with adult population density, and then by subsequent active larval choice at smaller scales. Factors influencing larval settlement have been listed as light, substratum inclination and texture (Havenhand & Svane, 1989). On a larger scale, hydrodynamics probably determine the distribution (Olson, 1985; Young, 1986). Although the ascidian tadpole larva has a short life in the plankton, recruitment, and recovery in ascidians is rapid. For example, Sebens (1985; 1986) described the recolonization of epifauna on vertical rock walls. Rapid colonizers such as encrusting corallines, encrusting bryozoans, amphipods, and tubeworms recolonized within 1-4 months. Ascidians such as *Dendrodoa carnea*, *Molgula manhattensis* and *Aplidium* spp. achieved significant cover in less than a year.

Resilience assessment. The above evidence suggests that *Ophiura* spp are opportunistic species, widely distributed around the coasts of the British Isles and North East Atlantic, that can reach high abundances in suitable substrata. Their recovery is likely to be rapid (<2 yr., 'High' resilience). Where *Virgularia mirabilis* survives impact undamaged, that is resistance is 'High', recovery is likely to be rapid; a resilience of 'High' (<2 years). However, where a proportion of the population is removed or killed then, although the species has a high dispersal potential and long-lived benthic larvae, larval recruitment is probably sporadic and patchy and growth is slow, suggesting that recovery may take many years; a resilience of 'Low' (>10 years). There was little evidence regarding the resilience of *Cerianthus lloydii*. Therefore, a resilience of 'Medium' (2 – 10 years) is suggested for all resistance levels ('None', 'Low', 'Medium' or 'High') based on expert judgement. The resilience of *Pecten maximus* populations is likely to be variable, depending on local hydrography and larval supply, so that they could recover with a couple of years or take many years so that a resilience of 'Medium' (2-10 years) is suggested. However, recovery may be prolonged in self-recruiting populations in isolated areas.

Therefore, the resilience of the biotope is likely to be **'Low'** (10 -25 years) as *Virgularia mirabilis* is the dominant important characterizing species. *Pecten maximus* and *Cerianthus lloydii* may also take many years to recover from a reduction in abundance or extent (e.g., resistance is Medium to None). The assessment is based on the reproduction and life history characteristics of the important characteristic species, or similar species rather than direct evidence, except in the case of *Pecten maximus*. Therefore, while confidence in the quality of the evidence and its concordance is 'Medium', confidence its application in 'Low'. CSaMu.VirOphPmax.Has is distinguished by the presence of hydroid and ascidian epifauna on small stones and pebbles. Recruitment and recovery in hydroids and most ascidians are likely to be rapid (with 2 years) so that the overall resilience assessment of '**Low**', based on *Virgularia mirabilis*, remains unaffected.

Hydrological Pressures

	Resistance	Resilience	Sensitivity

Temperature increase (local)	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

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. 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.

Ophiura albida is distributed from northern Norway to the Azores and the Mediterranean while *Ophiura ophiura* is distributed from northern Norway to Madeira and the Mediterranean (Hayward & Ryland, 1990). Little evidence on temperature tolerance was found. Wood *et al.* (2010) exposed *Ophiura ophiura* to 10.5°C and 15°C in the laboratory; temperatures that they suggested were normal for spring and summer in the waters of Plymouth, UK. They reported a seven-fold increase in metabolic rate (measured as oxygen uptake) between 10.5°C and 15°C (an increase of 4.5°C), together with an increase in speed of movement, but no mortality in the 40 day experiment. *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.

Pecten maximus occurs along the European Atlantic coast from northern Norway, south to the Iberian Peninsula and has been reported off West Africa, the Azores, Canary Islands and Madeira (Marshall & Wilson, 2009). Temperature is considered by many to be the primary trigger in spawning among Pectinidae (Marshall & Wilson, 2009) and there is some evidence to suggest that there may be a critical range (Barber & Blake, 1991). In the Bay of Brest and the Bay of St Brieuc in France, for instance, the critical temperature range for spawning is thought to be between 15.5 -16°C (Paulet *et al.*, 1988). No information was available on an upper threshold of temperature tolerance for adult *Pecten maximus* although Gruffydd & Beaumont (1972) observed high larval mortality above 20°C.

Gili & Hughes (1995) reported that temperature was a critical factor stimulating or preventing reproduction and that most species have an optimal temperature for reproduction. However, limited evidence for thermal thresholds and thermal ranges were available for the characterizing species recorded in this biotope. Cantero *et al.* (2002) describe the presence and year-round fertility of *Obelia dichotoma*, *Kirchenpaureria pinnata*, *Nemertesia ramosa* and *Halecium spp.*in the Mediterranean, indicating probable tolerance to temperature increases at the benchmark level. *Ascidia mentula* and *Corella parallelogramma* are recorded from north of Norway, throughout the British Isles and south into the Mediterranean (OBIS, 2018).

The distribution of the important characterizing species *Virgularia mirabilis*, *Ophiura* spp., *Cerianthus lloydii*, *Pecten maximus*, hydroids and ascidians suggest that they are probably resistant of 2°C change in temperature for a year. Exposure to a short-term acute increase of 5°C may interfere with reproduction may cause *Virgularia mirabilis* and *Cerianthus lloydii* to withdraw into their burrows temporarily, have a limited effect on *Ophiura ophiura*, but potentially interfere with spawning in *Pecten maximus*. 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)	Medium Q: Low A: NR C: NR	High Q: Low A: NR C: NR	Low Q: Low A: Low C: Low

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. 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.

Ophiura albida is distributed from northern Norway to the Azores and the Mediterranean while *Ophiura ophiura* is distributed from northern Norway to Madeira and the Mediterranean (Hayward & Ryland, 1995). Little evidence on temperature tolerance was found. Wood *et al.* (2010) exposed *Ophiura ophiura* to 10.5°C and 15°C in the laboratory; temperatures that they suggested were normal for spring and summer in the waters of Plymouth, UK. They reported a seven-fold increase in metabolic rate (measured as oxygen uptake) between 10.5°C and 15°C (an increase of 4.5°C), together with an increase in speed of movement, but no mortality in the 40 day experiment. *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. 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.*

Pecten maximus occurs along the European Atlantic coast from northern Norway, south to the Iberian Peninsula and has been reported off West Africa, the Azores, Canary Islands and Madeira (Marshall & Wilson, 2009). Temperature is considered by many to be the primary trigger in spawning among Pectinidae (Marshall & Wilson, 2009) and there is some evidence to suggest that there may be a critical range (Barber & Blake, 1991). In the Bay of Brest and the Bay of St Brieuc in France, for instance, the critical temperature range for spawning is thought to be between 15.5 -16°C (Paulet *et al.*, 1988). No information was available on an upper threshold of temperature tolerance for adult *Pecten maximus* although Gruffydd & Beaumont (1972) observed high larval mortality above 20°C. However, Crisp (1964) reported mortalities approaching 100% of *Pecten maximus* from several areas around the British coast in the severe winter of 1962-1963 where the average sea temperature fell by approximately 4°C.

Gili & Hughes (1995) reported that temperature was a critical factor stimulating or preventing reproduction and that most species have an optimal temperature for reproduction. However, limited evidence for thermal thresholds and thermal ranges were available for the characterizing species recorded in this biotope. Palerud *et al.* (2004) described the presence of the characterizing hydroids *Halecium halecinum* and *Nemertesia* sp. in Svalbard, suggesting that these hydroids are probably tolerant of the lowest temperatures they are likely to encounter in Britain and Ireland of ca 4°C (Beszczynska-Möller & Dye, 2013). *Ascidia mentula* and *Corella parallelogramma* are recorded from north of Norway, throughout the British Isles and south into the Mediterranean (OBIS, 2018).

Sensitivity assessment. The distribution of the important characterizing species *Virgularia mirabilis*, *Ophiura* spp., *Cerianthus lloydii*, *Pecten maximus*, hydroids and ascidians suggest that they are probably resistant of 2°C change in temperature for a year. Exposure to a short-term acute decrease of 5°C may interfere with reproduction may cause *Virgularia mirabilis* and *Cerianthus lloydii* to withdraw into their burrows temporarily, have a limited effect on *Ophiura ophiura*. However, *Pecten maximus* may suffer some mortality, especially in the shallower examples of the biotope. Therefore, a resistance of '**Medium'** is suggested with Low confidence to represent the loss of *Pecten maximus* while the other species in the biotope remain. Resilience is probably **'High'** so that the biotope is assessed as **'Low**' sensitivity at the benchmark level.

Salinity increase (local)	Medium 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.

For *Pecten maximus*, Christophersen & Strand (2003) found that, in the laboratory, the shells of spat held in water with a low salinity (20 ppt) became thin and easily damaged, which ultimately led to a negative shell growth rate. The scallops made fewer foot movements and retracted the mantle from the shell margin. Laing (2002) found that between 13-21°C the growth rate was significantly lower at 26 psu than at 28-30 psu.

The MNCR database indicates biotopes where *Ophiura albida* and *Ophiura ophiura* are characterizing species occur in full (30-40 units) as well as variable salinity (18-40 units). Echinoderms 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). *Ophiura albida* from Loch Etive, Scotland tolerated 20.7‰ (Pagett, 1980; Russell, 2013) and only a single individual died at this salinity. The LT50 for 40% seawater (ca 14‰) varied between ca 80 hours ca 400 hours depending on the origin of the specimens. Pagett (1980) noted that salinity tolerance was greatest in those specimens taken from waters at 70% seawater at the head of Loch Etive when compared to those at full salinity near the mouth of the Loch. Wolff (1968) reported that adult *Ophiura albida* were not seen at salinities below 16.5‰ Cl. Russell (2013) noted that *Ophiura ophiura* tolerated 27‰.

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 (CSaMu.VirOphPmax) 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. However, the hypersaline effluent is likely to sink to the seabed and may affect the community. Based on the evidence from Ruso *et al.* (2006) and Roberts *et al.* (2010) it is likely that the community will be degraded and, especially, *Ophiura* and *Pecten maximus* will leave the affected area or be killed. The effect on sea pens and anemones is unknown. Therefore, a resistance of **'Medium'** 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 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.

For *Pecten maximus*, Christophersen & Strand (2003) found that, in the laboratory, the shells of spat held in water with a low salinity (20 ppt) became thin and easily damaged, which ultimately led to a negative shell growth rate. The scallops made fewer foot movements and retracted the mantle from the shell margin. Laing (2002) found that between 13-21°C the growth rate was significantly lower at 26 psu than at 28-30 psu.

The MNCR database indicates biotopes where *Ophiura albida* and *Ophiura ophiura* are characterizing species occur in full (30-40 units) as well as variable salinity (18-40 units). Echinoderms 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). *Ophiura albida* from Loch Etive, Scotland tolerated 20.7‰ (Pagett, 1980; Russell, 2013) and only a single individual died at this salinity. The LT50 for 40% seawater (ca 14‰) varied between ca 80 hours ca 400 hours depending on the origin of the specimens. Pagett (1980) noted that salinity tolerance was greatest in those specimens taken from waters at 70% seawater at the head of Loch Etive when compared to those at full salinity near the mouth of the Loch. Wolff, 1968 reported that adult *Ophiura albida* were not seen at salinities below 16.5‰ Cl. Russell (2013) noted that *Ophiura ophiura* tolerated 27‰. Similarly, *Kirchenpaureria pinnata* and the *Nemertesia spp.* were recorded from biotopes at full and variable salinity, while ascidians *Ascidia mentula* and *Corella parallelogramma* were recorded from biotopes at full, variable and reduced salinities (Connor *et al.*, 2004).

Sensitivity assessment. CSaMu.VirOphPmax.HAs 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. A decrease in salinity at the benchmark level would result in a reduced salinity regime. The majority of the important characterizing species (e.g. *Virgularia mirabilis*) are only found in full salinity conditions, except *Ophiura albida* and the characteristic hydroids and ascidians. Therefore, such a reduction in salinity would probably result in mobile species leaving the biotope, the death of species that could not relocate, and a marked reduction in species richness. Therefore, a resistance of '**Low**' is recorded based on expert judgement. Resilience is probably also '**Low'** so that sensitivity is assessed as **'High'**.

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

CSaMu.VirOphPmax 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. However, CSaMu.VirophPmax.Has occurs in moderately strong to very weak tidal streams and has a higher coarse sediment content (sand, gravel or shell), although it probably occurs at greater depths in areas of moderately strong tidal flow. *Virgularia mirabilis* occurs in coarser sandier muds with small stones and shell fragments (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.*, 1997b).Therefore, it is likely to have a high tolerance to changes in water flow regimes. *Pecten maximus* lives embedded in recesses in the seabed usually with the upper valve flush with the sediment surface. This position can facilitate feeding by bringing the inhalant current near to the seabed, therefore, increasing the intake of detritus (Mason, 1983). It can also reduce the vulnerability of the scallop to dislodgment through increased water flow rate and wave action. Growth rates of scallops are generally faster in areas of relatively strong currents and reduced growth rates can occur in areas of low current speeds due to food limitation. However, excessive particle enrichment, commonly associated with areas of high water flow rate, may reduce the effectiveness of the feeding apparatus and reduce ingestion rates (Gibson, 1956). A reduction in water flow rate may reduce the availability of food particles but it is not likely that this reduction would adversely affect the growth and general condition of the scallop. Bricelj & Shumway (1991) suggested that scallops can compensate for short-term changes in the availability of food by adjusting the clearance rate of food particles. *Pecten maximus* is recorded from biotopes in moderately strong to very weak tidal flow (Connor *et al.*, 1997b).

Ophiura albida and *Ophiura ophiura* are both recorded in biotopes from very weak to moderately strong (negligible - 1.5m/s) tidal flow (Connor *et al.*, 1997b). Both species are reported to occur on a range of soft sediments (Hayward & Ryland, 1990) including muds, gravel, sand and shell (Boos *et al.*, 2010). *Ophiura albida* showed a preference for fine sediments due to its habit of burrowing to escape predators, and its preference for surface deposit feeding and scavenging or predating on fine grained sediments (Boos *et al.*, 2010). *Ophiura ophiura* is larger and demonstrated a little preference of sediment type due to its habit of escaping predators by rapidly moving across the surface of the sediment, together with its relatively unselective predation and scavenging habit (Boos *et al*., 2010). *Kirchenpaureria pinnata* and the ascidians *Ascidia mentula* and *Corella parallelogramma* were recorded from biotopes at moderately strong to very weak flow, while *Nemertesia* spp. were also recorded in strong or very strong flow (Connor *et al*., 2004).

Sensitivity assessment. CSaMu.VirOphPmax.Has are recorded 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. *Ophiura* spp. and *Pecten maximus* are unlikely to be affected adversely. However, *Virgularia mirabilis* may be directly affected by an increase in flow, especially if it exceeds 0.5 m/s. Therefore, a potential reduction in the *Virgularia mirabilis* abundance may result in the 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

CSaMu.VirOphPmax and CSaMu.VirOphPmax.Has occur in moderately wave exposed to very wave sheltered areas (Connor *et al.* 2004). As the biotope is dominated by fine muddy sediments it probably occurs are greater depth in the wave exposed rather than wave sheltered areas. *Virgularia mirabilis* occurs in coastal areas and inner sea lochs but these areas are still sheltered from wave action, and in sandier muds (Hughes, 1998a; Greathead *et al.* 2007). *Cerianthus lloydii* is recorded from biotopes from wave exposed to extremely sheltered muddy and in mixed or coarse sediments (Connor *et al*., 1997b). Therefore, it is likely to tolerate changes in wave action. *Ophiura albida* is recorded from extremely sheltered to very exposed biotopes and *Ophiura ophiura* from very sheltered to extremely exposed biotopes (Connor *et al*., 1997b). *Pecten maximus* is recorded from extremely wave sheltered to wave exposed biotopes. *Ascidia mentula* was recorded from wave sheltered to extremely sheltered biotopes, while *Corella parallelogramma*, *Kirchenpaureria pinnata* and *Nemertesia antennina* were recorded in more wave exposed biotopes and *Nemertesia ramosa* was recorded from biotopes in extremely wave exposed to sheltered conditions (Connor *et al*., 2004).

Sensitivity assessment. A decrease in wave exposure is unlikely in the sheltered habitats typical of this biotope. An increase in wave exposure is likely to affect *Virgularia mirabilis* 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 examples of 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: Medium A: Medium 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.

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 pycnocline in the Gulf of Trieste resulted in a mass mortality of benthos between 12 and 26th September 1983 (Stachowitsch, 1992b), 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 *Truncylariopsis trunculus* and the sphinuculid *Sipunculus nudis* (Stachowitsch, 1992b).

Ophiura albida showed a definite resistance to low oxygen levels with 50% of individuals still surviving after 32 hours in seawater with an oxygen concentration of 0.21 mg/l (Theede *et al*., 1969). Rosenberg *et al*. (1991) suggest that some part of the benthic community, including *Amphiura filiformis*, can withstand oxygen concentrations of around 1 mg/l for several weeks. However, Vistisen & Vismann (1997) noted that the epibenthic *Ophiura albida* was less tolerant of deoxygenation than *Amphiura filiformis*. *Ophiura albida* survived at 10% oxygen saturation for a month but experienced 50% mortality (LT50) after 2.5 days at <1%(anoxia) No information *Ophiura ophiura* was found.

Scallops are incapable of sustaining prolonged valve closure and are relatively intolerant of anoxia (Bricelj & Shumway, 1991). Brand & Roberts (1973) found that scallops transferred to de-oxygenated water (13 mmHg; 0.76 mg O_2/l) for three hours experienced rapid bradycardia (reduced heart rate). However, the length of exposure time set in the benchmark is one week which is significantly longer than the length of Brand & Roberts (1973) experimental work. It is likely that scallops will experience some respiratory stress at the benchmark level. It is possible that feeding will be reduced and the animal may become lethargic thus making it more susceptible to predation due to a weakened escape response. This will reduce the viability of the population. However, Brand & Roberts (1973) found that the scallops that had been exposed to the deoxygenated water recovered well upon return to well-oxygenated water (135 mmHg; 7.9 mg O_2/l).

Hydroids mainly inhabit environments in which the oxygen concentration exceeds 5 ml/l (ca 7 mg/l) (Gili & Hughes, 1995). Although no information was found on oxygen consumption for the characterizing hydroids, Sagasti *et al.* (2000) reported that epifaunal species, including several hydroids and *Obelia bidentata (*as *bicuspidata)* in the York River, Chesapeake Bay, tolerated summer hypoxic episodes of between 0.5 and 2 mg O_2/l (0.36 and 1.4 ml/l) for 5-7 days at a time, with few changes in abundance or species composition. Hiscock & Hoare (1975) reported an oxycline forming in the summer months (Jun-Sep) in a quarry lake (Abereiddy, Pembrokeshire) from close to full oxygen saturation at the surface to <5% saturation (ca 0.5 mg/l) below ca 10 m. Despite the presence of *Kirchenpaueria pinnata*, *and Ascidia mentula* in shallower water, no sponges or ascidians were recorded at depths below the oxycline at 10 -11 m. The ability of solitary ascidians to withstand decreasing oxygen levels has not been well documented. Mazouni *et al.* (2001) noted that whilst oysters (*Magallana gigas*) can survive short-term exposure to periods of anoxia (Thau Lagoon, France), the associated biofouling community dominated by *Ciona intestinalis* suffered heavy mortality. It should be noted, however, that *Ciona intestinalis* is frequently found in areas with restricted water renewal where oxygen concentrations may drop (Carver *et al*., 2006). In addition, in a systematic review of the effects of hypoxia cnidarians were amongst the most tolerant groups studied (Vaquer-Sunyer & Duarte, 2008).

Sensitivity assessment. The evidence suggests that severe hypoxic or anoxic conditions are likely to be detrimental to sea pens while *Cerianthus lloydii* may survive even anoxic conditions for a week.   *Pecten maximus* can survive short-term changes in oxygen levels and aerial exposure but prolonged exposure may be detrimental as it cannot close its valves tightly. It may flee affected areas. Similarly, *Ophiura albida* may experience some mortality at the benchmark level or significant mortality in anoxic conditions. Therefore, a resistance of **'Low'** is suggested to represent the loss of a proportion of the sea pen population, *Pecten maximus*, and *Ophiura* population. Resilience is probably **'Low**' due to the time required for the sea pen population to recover. 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).

A study in the Bay of Brest (Chauvaud *et al*., 1998) found that, regardless of the specific phytoplankton composition, high concentrations of chlorophyll-a reduced the daily growth rate of juvenile *Pecten maximus*. High concentrations of chlorophyll-a following diatom blooms have also been implicated in causing negative effects on the ingestion and respiration of *Pecten maximus* juveniles either by clogging their gills or by depleting the oxygen at the water-sediment interface during the degradation of organic matter (Lorrain *et al*., 2000). High levels of nutrient enrichment may lead to eutrophication and the possibility of subsequent increases in turbidity and suspended material and decreases in the amount of available oxygen, depending on other environmental conditions. A decrease in *Pecten maximus* growth rate and reproduction has been observed in the presence of certain toxic algal blooms (Chauvaud *et al*., 1998). For instance *Gymnodinium* cf. *nagasakiense* can lead to the death of post-larval and juvenile *Pecten maximus* in the wild (Erard-Le Denn *et al*., 1990, cited in Chauvaud *et al*., 1998) and in 1995, three major blooms of *Gymnodinium* cf. *nagasakiense* in the Bay of Brest inhibited the settlement of spat, although a rapid return to normal shell growth rates was reported once the numbers of *Gymnodinium* sp. had decreased (Chauvaud *et al*., 1998). In contrast, Reitan *et al*. (2002) experimentally enhanced the nutrient supply in a landlocked bay in Norway and found that the resulting increase in the phytoplankton biomass had a significant positive effect on growth rates of *Pecten maximus*.

Borja *et al*. (2000) and Gittenberger & van Loon (2011) assigned *Cerianthus lloydii* to their Ecological Group I, 'species very sensitive to organic enrichment and present under unpolluted conditions (initial state)'. But *Amphiura filiformis*, *Ophiura albida* and *Ophiura ophiura* were assigned to their Ecological Group II (Species indifferent to enrichment, always present in low densities with non-significant variations with time) (from the initial state to slight unbalance) (Gittenberger & van Loon, 2011). The basis for their assessment and relation to the pressure benchmark is not clear. Both *Ophiura* spp. are capable of surface deposit feeding and may benefit from some organic enrichment at the benchmark level.

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 or nutrient enrichment. *Ophiura* spp. may benefit from nutrient enrichment. However, algal blooms may be detrimental to *Pecten maximus*, depending on local conditions. Nevertheless, 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: Medium A: Low C: Medium	Low Q: Medium A: Low C: Medium	Medium Q: Medium A: Low C: Medium

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). Wilding (2011) noted that the abundance of *Pennatula phosphorea* was inversely correlated with predicted Infaunal Trophic Index (a predicted estimate of organic waste build-up) around salmon farms in Scotland, but that the effect only extended for 50m from the cages.

Borja *et al*. (2000) and Gittenberger & van Loon (2011) assigned *Cerianthus lloydii* to their Ecological Group I, 'species very sensitive to organic enrichment and present under unpolluted conditions (initial state)'. But *Amphiura filiformis*, *Ophiura albida* and *Ophiura ophiura* were assigned to their Ecological Group II (Species indifferent to enrichment, always present in low densities with non-significant variations with time) (from the initial state to slight unbalance) (Gittenberger & van Loon, 2011). The basis for their assessment and relation to the pressure benchmark is not clear. Both *Ophiura* spp. are capable of surface deposit feeding and may benefit from some organic enrichment at the benchmark level.

No evidence on the effects of organic enrichment on *Pecten maximus* was found. Although *Pecten maximus* occurs in this biotope, the areas with the highest abundance and the fastest growth rates of scallops are usually in areas with little mud (Brand, 1991). Gruffydd (1974) found that the maximum shell size of *Pecten maximus* from the north Irish Sea was significantly negatively correlated with increasing mud content in the sediment.

Witt *et al*. (2004) found that the hydroid *Obelia* spp. was more abundant in a sewage disposal area in the Weser estuary (Germany), which experienced sedimentation of 1 cm for more than 25 days. However, another hydroid (*Sertularia cupressina)* was reduced in abundance when compared with unimpacted reference areas. As suspension feeders, an increase in organic content at the benchmark is likely to be of benefit to the characterizing hydroids. There is some suggestion that there are possible benefits to the ascidians from the increased organic content of water; Ascidian 'richness' in Algeciras Bay was found to increase in higher concentrations of suspended organic matter (Naranjo *et al.* 1996). Kocak & Kucuksezgin (2000) noted that *Ciona intestinalis* was one of the rapid breeding opportunistic species that tended to be dominant in Turkish harbours enriched by organic pollutants and was frequently found in polluted environments (Carver *et al*., 2006). *Ascidia mentula* has been reported in Iberian bays subject to both nutrient-rich upwelling events and anthropogenic organic pollution (Aneiros *et al*., 2015).

An increasing gradient of organic enrichment (e.g. in the vicinity of point sources of organic-rich effluent or sewage sludge dump sites) 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). The effects of organic enrichment on burrowing megafauna and other infauna depended on the degree of enrichment and any resultant hypoxia, which depend on the sediment type and local hydrology.

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. *Ophiura* spp. may benefit from organic enrichment at the benchmark level but *Cerianthus* may be lost. It is unclear what effect organic enrichment may have on *Pecten maximus* within the biotope. Therefore, a precautionary resistance of '**Medium**' is suggested and, as resilience is probably '**Low**', a sensitivity is assessed as **'Medium'.**

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 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, burrowing anemones, epibenthic brittlestars or infauna.

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

Physical change (to another sediment type)	Low 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. In addition, a 'mud' substratum was the most important factor in a habitat suitability index model for sea pens developed by Greathead *et al.* (2015). In their model, *Pennatula phosphorea* and *Virgularia mirabilis* had their maximum habitat suitability at 100% mud. All three British sea pen 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 there were no records of *Pennatula phosphorea* 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. Similarly, *Pecten maximus* is recorded from gravel, coarse and fine clean sand, muddy sand and sandy muds. *Ophiura albida* and *Ophiura ophiura* are both reported to occur on a range of soft sediments (Hayward & Ryland, 1990) including muds, gravel, sand and shell (Boos *et al*., 2010). *Ophiura albida* showed a preference for fine sediments due to its habit of burrowing to escape predators, and its preference for surface deposit feeding and scavenging or predating on fine grained sediments (Boos *et al.*, 2010). *Ophiura ophiura* is larger and demonstrated a little preference of sediment type due to its habit of escaping predators by rapidly moving across the surface of the sediment, together with its relatively unselective predation and scavenging habit (Boos *et al.*, 2010).

Sensitivity assessment. While the important characteristic species are recorded from a range of sediment types, CSaMu.VirOphPmax.HAs is defined by its occurrence in sandy gravelly mud with shell and small stones (Connor *et al.*, 2004). Therefore, a change in sediment type by one Folk class (see Long, 2006), e.g. from ‘sandy mud’ to ‘sand’ or from ‘sandy or gravelly mud’ to ‘muddy gravel’ would result in loss of the biotope. Therefore, a resistance of **'None'** is recorded. As the change is defined as 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. *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 for sizes) 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, *Ophiura spp.* only burrow into the surface of the sediment while *Pecten maximus* lives embedded in recesses in the seabed usually with the upper valve flush with the sediment surface.

Sensitivity assessment. Extraction of sediment to 30 cm (the benchmark) could remove most of the resident sea pens present, the burrowing sea anemones, and epifauna, 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: Medium 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. otter trawling (Ball *et al.*, 2000; Collie *et al.*, 2000). Tracks left by otter boards 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 boards 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. In *Virgularia mirabilis* withdrawal from a 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 an 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* was found. Greathead *et al.* (2011) were not able to conclude if the variation in *Cerianthus* abundance in the Fladen Ground was due to miscounting, its patchy distribution, or fishing activity.

Pecten maximus is the target of commercial fisheries and hence, gears have been developed to capture this species. By-catch studies suggest that due to their robust shells captured *Pecten maximus* suffer low rates of damage. Jenkins *et al.* (2001) found that less than 10% of scallops encountering dredges showed any signs of external physical damage on a scallop fishing ground in the north Irish Sea. Undamaged *Pecten maximus* captured using dredges, show low levels (5%). of mortality in the laboratory (Jenkins *et al.*, 2001). Similarly (Bergmann *et al.*, 2001) found that most (98%) of queen scallops *Aequipecten opercularis* were undamaged when retained in otter trawl hauls in the Clyde Seas *Nephrops* fishery. Damage was restricted to chipping of the outer shell. Ansell *et al.* (1991) however, stated that up to 19% of the scallops left behind by a dredge are affected to some extent. Individuals with damaged shells are more prone to predation. However, Jenkins *et al.* (2001) reported that, during dredging, more than 90% of *Pecten maximus* that came into contact with a dredge (including those landed, discarded and left behind by the dredge) were in good condition overall and showed little or no shell damage. The differences between reported rates of effect may be due to different classification systems used to score impacts. Blyth *et al.* (2004) compared sites that were trawled for scallops to those that were untrawled or previously trawled but not in the 18-24 months prior to the study. They found that significantly fewer scallops were caught in the trawled sites. They suggested that at least a two year period was necessary for the benthic community to recover to a state that was indistinguishable from non-trawled areas.

Ophiura ophiura is a common by-catch in *Nephrops* otter trawl fishery in the Clyde Sea. Bergmann *et al.* (2001) reported that 100% of the *Ophiura ophiura* catch as by-catch were damaged. Damage ranged from broken arms to broken discs, and damage increased with animal size. However, Bergmann & Moore (2001b) noted that post-trawling mortality of discarded *Ophiura ophiura* was 100% within 14 days and that even immediate re-emersion in seawater only reduced mortality to 91%. In contrast, Bradshaw *et al.* (2000, 2002) noted that *Ophiura albida* was consistently more abundant in gravelly sediments dredged by scallop dredges around the Isle of Man, presumably due to their good powers of regeneration and small size. *Ophiura ophiura* and *Ophiura albida* were recorded regularly in baited traps, sometimes in relatively high numbers, indicating that these species are mobile and exhibit scavenging behaviour (Groenewold & Fonds, 2000). *Ophiura ophiura* has been observed scavenging in trawl tracks after the passage of a scallop dredge although divers noted that many were damaged (Ramsay *et al*., 1998). Bradshaw *et al.* (2002) also noted that small tunicates (e.g. *Ascidiella*) and hydroids (e.g. *Nemertesia*) were also more abundant in scallop dredged areas, presumably due to their ability to recover rapidly.

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 and sandy muds are likely to be vulnerable to fishing activities. *Cerianthus lloydii* will probably withdraw into the sediment to avoid surface abrasion by trawls or pots. While *Ophiura ophiura* is common by-catch and probably suffers high mortality as a result, it can probably recover quickly and the smaller *Ophiura albida* may increase in abundance. 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). *Pecten maximus* may be directly targeted and a proportion of the population removed although scallop dredge efficiency is relatively low (Dare *et al.* 1993). 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	Low Q: High A: Medium C: Medium	Low Q: Medium A: Low C: Medium	High Q: Medium A: Low C: Medium

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 and sandy muds are likely to be vulnerable to fishing activities. Based on the evidence presented under abrasion, *Cerianthus lloydii* will probably withdraw into the sediment to avoid surface abrasion by trawls or pots. While *Ophiura ophiura* is common by-catch and probably suffers high mortality as a result, it can probably recover quickly and the smaller *Ophiura albida* may increase in abundance. *Pecten maximus* may be directly targeted and a proportion of the population removed although scallop dredge efficiency is relatively low (Dare *et al.* 1993). 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). But, penetrative gear is likely to remove a proportion of the sea pen population, as it may remove them from their burrows, within the footprint of the activity. Therefore, a resistance of **'Low'** is recorded due to the potential disturbance to the biotope as a whole. The resilience is probably '**Low'** so that sensitivity is assessed as **'High'**.

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

The sea pens live in wave 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 that 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.

Growth rates of adult *Pecten maximus* are adversely affected by increases in suspended sediments concentrations (Bricelj & Shumway, 1991) and excessive particle bombardment may threaten the viability of the feeding apparatus (Gibson, 1956), thereby potentially decreasing ingestion rates. Szostek *et al.* (2013) examined the effects of increased SPM and burial on juvenile *Pecten maximus*. The scallops were exposed to low (50-100 mg/l SPM) and high (200-700 mg/l SPM) for 18 days in pVORT systems. Shell claps and movements were significantly higher under high rather than low SPM or control (no SPM) but growth rates (over the 18 days) were significantly lower under both low and high SPM than under control conditions. The energetic cost resulted in lower growth rates (Szostek et al., 2013). Szostek et al. (2013) noted that while the short-term survival (over the 18 day experiment) of *Pecten maximus* was not affected by SPM levels but that longer-term survival required further investigation.

An increase in suspended sediment is unlikely to interfere with feeding in *Cerianthus lloydii*, which is a passive predator. *Ophiura ophiura* and *Ophiura albida* are both found in a range of sediments, although *Ophiura albida* has a preference for fine sediments. Both species are omnivorous but *Ophiura albida* is preferentially a deposit feeder while *Ophiura ophiura* is mainly a predator or scavenger (Boos *et al*., 2010), and therefore unlikely to be affected by changes in suspended sediment. Other members of the infaunal community are deposit feeders, predators or omnivores and unlikely to be affected.

Sensitivity assessment. 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. However, an increase in turbidity, from clear to turbid over the course of a year, (similar to the 'high SPM' studied by Szostek *et al*., 2013) could result in some mortality of the *Pecten maximus* population due to an increase in energy expenditure and reduced feeding. Therefore, resistance is assessed as **'Medium'.** Resilience is probably **'Medium'** so that the biotope is assessed as **'Medium'** sensitivity at the benchmark level.

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

Natural accretion rates are potentially high in 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 (Schafer, 1962, cited in Bromley, 2012). Bromley (2012) 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.

Direct evidence for the effects of siltation on this ecological group is limited to the experiments undertaken by Last *et al.* (2011). Last *et al.* (2011) buried *Ophiura ophiura* individuals under three different depths of sediment; shallow (2 cm), medium (5 cm) and deep (7 cm). The results indicated that *Ophiura ophiura* is highly tolerant of short-term (32 days) burial events, with less than 10% mortality of all buried specimens. This is largely a reflection of the ability of the species to re-emerge from all depths across all sediment fractions tested. Survival of specimens that remained buried was low, with 100% mortality of individuals that remained buried after 32 days. Percentage mortality increased with both depth and duration of burial. The experiments utilised three different fractions of kiln dried, commercially obtained marine sediment: coarse (1.2-2.0 mm diameter), medium fine (0.25-0.95 mm diameter) and fine (0.1-0.25 mm diameter). *Ophiura ophiura* are found in sandier habitats that are subject to high rates of natural disturbance, these species are therefore likely to experience burial through natural sediment movements and be adapted to this, as suggested by the results of experimental smothering (Last *et al.*, 2011). No evidence for re-emergence thresholds was found. No direct evidence was found on *Ophiura albida*. However, it is smaller and less mobile than *Ophiura ophiura* (Boos *et al.*, 2010) and may, therefore, be more vulnerable to smothering.

Szostek *et al.* (2013) examined a variety of burial duration (1-8 days), depth of burial (0 to 5cm) and size fraction of the sediment (fine: 0.1-0.3 mm, medium fine: 0.4-0.8 mm and coarse: 1.2-2 mm diameter) on juvenile *Pecten maximus*. Emergence was higher at shallow depth and in coarse to medium sediment. At shallow depths scallops emerged almost immediately or within 1 day except for fine sediments where no scallops emerged from under 3 or 5 cm of burial. Mortality was low under coarse and medium sediment and was unrelated to depth as only 4 of the 27 that remained buried died. But mortality was under fine sediment increased with depth, as 15 out of 27 scallops that remained buried died, and with increased duration, 100% mortality was observed after 4 and 8 days of burial.

In general, it appears that hydroids are sensitive to silting (Boero, 1984; Gili & Hughes, 1995) and the decline of beds in the Wadden Sea have been linked to environmental changes including siltation. Round *et al.* (1961) reported that the hydroid *Sertularia* (now *Amphisbetia*) *operculata* died when covered with a layer of silt after being transplanted to sheltered conditions. Boero (1984) suggested that deepwater hydroid species develop upright, thin colonies that accumulate little sediment, while species in turbulent water movement were adequately cleaned of silt by water movement. Hughes (1977) found that maturing hydroids that had been smothered with detritus and silt lost most of the hydrocladia and hydranths. After one month, the hydroids were seen to have recovered but although neither the growth rate nor the reproductive potential appeared to have been affected, the viability of the planulae may have been affected. *Nemertesia ramosa* is an upright hydroid with a height of up to 15 cm and *Nemertesia antennina* grows up to 25 cm and *Kirchenpaueria pinnata* grows up to 10 cm in height (Hayward & Ryland, 1994). The structure of *Nemertesia* spp. is fairly tough and flexible, and *Nemertesia* spp. are recorded from sediment scoured methane-derived authigenic carbonates in the mid-Irish Sea (Whomersley *et al.*, 2010b; O'Reilly *et al.*, 2014). Smothering with 5 cm of sediment may cover over some individuals; others may just have the lower section of the main stem covered.

The solitary ascidians are attached permanently to the substratum and are active suspension feeder. *Ascidia mentula* is a large solitary sea squirt that can be over 18 cm in length but is attached on its left side and does not protrude above the substratum and *Corella parrallelogramma* is up to 5 cm in height. The complete disappearance of the sea squirt *Ascidiella aspersa* biocoenosis and ‘associated sponges’ in the Black Sea near the Kerch Strait was attributed to siltation (Terent'ev, 2008 cited in Tillin & Tyler-Walters, 2014).

Sensitivity assessment. Both *Virgularia* and *Cerianthus* can withdraw into their tube and can probably re-emerge through 5 cm of fines. However, experimental studies have demonstrated juvenile *Pecten maximus* are killed under 5 cm of fine sediment and that *Ophiura ophiura* suffered some mortality. Smothering by 5 cm of sediment is may also result in mortality amongst the characteristic ascidians and smaller specimens of hydroids. Therefore, a resistance of **'Medium'** is suggested due to the potential loss in abundance of one or more of the characterizing species. The resilience of *Pecten maximus* is probably **'Medium'** so that the biotope is probably of **'Medium'** sensitivity to siltation and smothering at the benchmark level.

Smothering and siltation rate changes (heavy)	None Q: High A: Medium C: Medium	Medium Q: Medium A: Low C: Medium	Medium Q: Medium A: Low C: Medium

Sensitivity assessment. Based on the evidence presented above (siltation, 5 cm deposition), 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, experimental studies have demonstrated *Pecten maximus* is killed under 5 cm of fine sediment and that *Ophiura ophiura* suffered some mortality so that 30 cm of fines is likely to result in further mortality in *Pecten maximus* and *Ophiura* spp. In addition, the epifaunal community of hydroids and ascidians is likely to be completely smothered and may be lost. Therefore, **technically the biotope VirOphPmax.HAs would be lost and the biotope replaced by VirOphPmax** so resistance is assessed as **'None'**. Once the deposited sediment is removed or redistributed and shell and small stones reappear, the hydroids and ascidians would recolonize quickly. However, resilience is probably '**Medium**' based on the recovery of *Pecten maximus* population, so that sensitivity of the biotope is probably **'Medium'** 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 and scallops, 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 a 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

This biotope is dominated by suspension feeders, 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 and scallops 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

The important characterizing species in this biotope are unlikely to be translocated or genetically modified. However, *Pecten maximus* has been the subject of intense genetic research to examine population structure, stock, fisheries and aquaculture (Beaumont & Zouros, 1991; Beaumont, 2011). In recent years, the potential for GMO and the development of commercial strains are under investigation (Beaumont, 2011). Brenner *et al.* (2014) reported that bivalve aquaculture transfers have been responsible for the inadvertent transfer of diseases, pests, non-natives. There is also the potential to affect the genetic integrity of local stocks. *Pecten maximus* was reported to carry the infectious pancreatic necrosis virus (of fin-fish) but although the virus persisted for a long period of time in the scallops, no viral propagation occurred. However, Brenner *et al.* (2014) note that scallops should be considered as a potential fish pathogen vector. Beaumont (2000) noted that the loss of genetic diversity is difficult to avoid in hatchery conditions but suggested that the potential risks and consequences of hybridization should be assessed experimentally before introductions were carried out. Beaumont (2000) suggested that sterile triploid scallops could be used but noted that reversion to diploidy may occur (Beaumont, 2000; Brenner *et al.*, 2014).

Overall, the translocation of scallop stocks may pose a risk of disease transfer but no direct evidence was found. Similarly, genetically modified scallops may pose a risk to the genetic integrity of wild scallop population but no evidence was found. Therefore, no assessment was made until further evidence becomes available.

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

Crepidula fornicata and *Codium fragile tomentosoides* have been reported to foul scallop beds (DAISIE, 2009) but no information on adverse effects was found. *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	Medium Q: Low A: NR C: NR	High Q: Low A: NR C: NR	Low Q: Low A: Low C: Low

Bivalves, such as scallops, are the host for numerous viruses, bacteria, and parasites, some of which cause disease in the shellfish themselves. For example, *Pecten maximus* has been reported to host infectious pancreatic necrosis virus (a fin fish virus), several species of *Vibrio*, rickettsales-like organisms (a bacterium), *Pseudoklossia pectinis* (a coccidia protist), *Polydora* spp. (a burrowing polychaete), *Modiolicola* spp. (a copepod) (McGladdery *et al.*, 2006). In most cases the virus, bacteria or parasite had no reported effect on the population studied. In France, the mass mortality of *Pecten maximus* larvae in scallop hatcheries was caused by *Vibrio* infection and mass mortalities of wild, cultured and captive scallops may have been associated with Rickettsial-like bacterial infections (McGladdery *et al.*, 2006). *Polydora* spp. also associated with shell damage in wild and cultured scallops.

Sensitivity assessment. No information on diseases in any of the important characterizing species was found. Therefore, a resistance of **'Medium'** is suggested to represent the loss of condition of the resident *Pecten maximus* population, and possible loss of recruitment (larvae) and some mortality. A resilience of **'High'** is suggested as the majority of the *Pecten* population may remain. Therefore, sensitivity is assessed as **'Low'** but with Low confidence.

Removal of target species	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Pecten maximus is the subject of commercial fishing activity and may be targeted via scallop dredging or hand collection. The physical effects of fishing activities are discussed under 'abrasion' and 'penetration' pressures above. While *Pecten maximus* occurs in low numbers in this biotope, it is an epibenthic suspension feeder and is unlikely to be dependent on any other member of the community for its survival. Similarly, no other member of the community is dependent on the scallop for its survival. Therefore,a resistance of **'High'** is recorded. Hence, resilience is **'High'**, and the biotope is assessed as **'Not sensitive'** to this pressure.

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, if the important characterizing species were removed as by-catch, the character of the biotope would change. A significant decline in the abundance of *Virgularia mirabilis* or *Pecten maximus* would result in loss of the biotope as recognised by the habitat classification. Therefore, a resistance of **'Medium'** is suggested. Resilience is probably **'Low'** so that sensitivity is assessed as **'Medium'**.

Bibliography

Ambrose, W.G. Jr., 1993. Effects of predation and disturbance by ophiuroids on soft-bottom community structure in Oslofjord: results of a mesocosm study. *Marine Ecology Progress Series*, **97**, 225-236.

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.

Aneiros, F., Rubal, M., Troncoso, J.S. & Bañón, R., 2015. Subtidal benthic megafauna in a productive and highly urbanised semi-enclosed bay (Ría de Vigo, NW Iberian Peninsula). *Continental Shelf Research*, **110**, 16-24.

Ansell, A.D., Dao, J. & Mason, J., 1991. Three European scallops: *Pecten maximus*, *Chlamys* (*Aequipecten*) *opercularis* and *C.* (*Chlamys*) *varia*. In *Scallops: biology, ecology and aquaculture* (ed. S.E. Shumway), pp. 715-751. Amsterdam: Elsevier. [Developments in Aquaculture and Fisheries Science, no. 21.]

Atkinson, R.J.A., 1989. Baseline survey of the burrowing megafauna of Loch Sween, proposed Marine Nature Reserve, and an investigation of the effects of trawling on the benthic megafauna. *Report to the Nature Conservancy Council, Peterborough, from the University Marine Biological Station, Millport*, pp.1-59.

Baden, S.P., Pihl, L. & Rosenberg, R., 1990. Effects of oxygen depletion on the ecology, blood physiology and fishery of the Norway lobster *Nephrops norvegicus*. *Marine Ecology Progress Series*, **67**, 141-155.

Ball, B.J., Fox, G. & Munday, B.W., 2000a. Long- and short-term consequences of a *Nephrops* trawl fishery on the benthos and environment of the Irish Sea. *ICES Journal of Marine Science*, **57**, 1315-1320.

Barber, B.J. & Blake, N.J., 1991. Reproductive physiology. In *Scallops: biology, ecology and aquaculture* (ed. S.E. Shumway), pp. 377-428. Amsterdam: Elsevier. [Developments in Aquaculture and Fisheries Science, no. 21.]

Beaumont, A., 2000. Genetic considerations in transfers and introductions of scallops. *Aquaculture International*, **8** (6), 493-512.

Beaumont, A., 2011. In *Scallops: Biology, Ecology and Aquaculture*, S.E. Shumway, & G.J. Parsons (eds) pp. 543-594. Amsterdam, Elsevier Science.

Beaumont, A.R. & Zouros, E., 1991. Genetics of scallops. In *Scallops: biology, ecology and aquaculture* (ed. S.E. Shumway), pp. 585-624. Amsterdam: Elsevier. [Developments in Aquaculture and Fisheries Science, no.21.]

Beaumont, A.R., 2005. Genetics. In *Scallops: biology, ecology and aquaculture* 2nd edn, (ed. S.E. Shumway and J. Parsons). Amsterdam: Elsevier (in press).

Bergman, M.J.N. & Hup, M., 1992. Direct effects of beam trawling on macro-fauna in a sandy sediment in the southern North Sea. *ICES Journal of Marine Science*, **49**, 5-11.

Bergmann, M. & Moore, P.G., 2001. Mortality of *Asterias rubens* and *Ophiura ophiura* discarded in the *Nephrops* fishery of the Clyde Sea area, Scotland. *ICES Journal of Marine Science*, **58**, 531-542.

Bergmann, M., Beare, D.J. & Moore, P.G., 2001. Damage sustained by epibentic invertebrates discarded in the *Nephrops* fishery of the Clyde Sea area, Scotland. *Journal of Sea Research*, **45**, 105-118.

Beszczynska-Möller, A., & Dye, S.R., 2013. ICES Report on Ocean Climate 2012. In *ICES Cooperative Research Report*, vol. 321 pp. 73.

Beukers-Stewart, B.D., Mosley, M.W.J & Brand, A.R., 2003. Population dynamics and predictions in the Isle of Man fishery for the great scallop. *ICES Journal of Marine Science*, **60**, 224-242.

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

Blyth, R.E., Kaiser, M.J., Edward-Jones, G. & Hart, P.J.B., 2004. Implications of a zoned fishery management system for marine benthic communities. *Journal of Applied Ecology*, **41**, 951-961.

Boero, F., 1984. The ecology of marine hydroids and effects of environmental factors: a review. *Marine Ecology*, **5**, 93-118.

Boos, K. & Franke, H.-D., 2006. Brittle stars (Echinodermata: Ophiuroidea) in the German Bight (North Sea)- species diversity during the past 130 years. *Journal of the Marine Biological Association of the United Kingdom*, **86** (5), 1187-1197.

Boos, K., Gutow, L., Mundry, R. & Franke, H.-D., 2010. Sediment preference and burrowing behaviour in the sympatric brittlestars Ophiura albida Forbes, 1839 and *Ophiura ophiura* (Linnaeus, 1758) (Ophiuroidea, Echinodermata). *Journal of Experimental Marine Biology and Ecology*, **393** (1–2), 176-181.

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.

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

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

Brand, A.R. & Roberts, D., 1973. The cardiac responses of the scallop *Pecten maximus* (L.) to respiratory stress. *Journal of Experimental Marine Biology and Ecology*, **13**, 29-43.

Brand, A.R., 1991. Scallop ecology: Distributions and behaviour. In *Scallops: biology, ecology and aquaculture* (ed. S.E. Shumway), pp. 517-584. Amsterdam: Elsevier. [Developments in Aquaculture and Fisheries Science, no.21.]

Bricelj, V.M. & Shumway, S., 1991. Physiology: energy acquisition and utilization. In *Scallops: biology, ecology and aquaculture* (ed. S.E. Shumway), pp. 305-346. Amsterdam: Elsevier. [Developments in Aquaculture and Fisheries Science, no. 21.]

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

Buchanan, J.B., 1964. A comparative study of some of the features of the biology of *Amphiura filiformis* and *Amphiura chiajei* (Ophiuroidea) considered in relation to their distribution. *Journal of the Marine Biological Association of the United Kingdom*, **44**, 565-576.

Cantero, Á.L.P., Carrascosa, A.M.G. & Vervoort, W., 2002. *The benthic hydroid fauna of the Chafarinas Islands (Alborán Sea, western Mediterranean)*: Nationaal Natuurhistorisch Museum.

Carver, C., Mallet, A. & Vercaemer, B., 2006. Biological synopsis of the solitary tunicate *Ciona intestinalis*. Canadian Manuscript Report of Fisheries and Aquatic Science, No. 2746, v + 55 p. Bedford Institute of Oceanography, Dartmouth, Nova Scotia.

Carver, C., Mallet, A. & Vercaemer, B., 2006. Biological synopsis of the solitary tunicate *Ciona intestinalis*. Canadian Manuscript Report of Fisheries and Aquatic Science, No. 2746, v + 55 p. Bedford Institute of Oceanography, Dartmouth, Nova Scotia.

Chauvaud, L., Thouzeau, G. & Paulet, Y.M., 1998. Effects of environmental factors on the daily growth rate of *Pecten maximus* juveniles in the Bay of Brest (France). *Journal of Experimental Marine Biology and Ecology*, **227**, 83-111.

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.

Christophersen, G. & Strand, O., 2003. Effect of reduced salinity on the great scallop (*Pecten maximus*) spat at two rearing temperatures. *Aquaculture*, **215**, 79-92.

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., 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.

Cornelius, P.F.S., 1992. Medusa loss in leptolid Hydrozoa (Cnidaria), hydroid rafting, and abbreviated life-cycles among their remote island faunae: an interim review.

Dahllöf, I., Blanck, H., Hall, P.O.J. & Molander, S., 1999. Long term effects of tri-n-butyl-tin on the function of a marine sediment system. *Marine Ecology Progress Series*, **188**, 1-11.

Dahm, C., 1993. Growth, production and ecological significance of *Ophiura albida* and *Ophiura ophiura* (Echinodermata: Ophiuroidea) in the German Bight. *Marine Biology*, **116**, 431-437.

DAISIE, 2009. *Handbook of Alien species in Europe*. Netherlands, Springer [Invading Nature
Springer Series In Invasion Ecology Volume 3]

Darby, C.D. & Durance, J.A., 1989. Use of the North Sea water parcel following model (NORSWAP) to investigate the relationship of larval source to recruitment for scallop (*Pecten maximus*) stocks of England and Wales. *ICES Council Meeting Papers*, K: 28.

Dare, P., Key, D. & Connor, P., 1993. The efficiency of spring-loaded dredges used in the western English Channel fishery for scallops, *Pecten maximus* (L.). ICES Council Meeting Papers C.M.1993/B:15.

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.

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

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

Eno, N.C., MacDonald, D. & Amos, S.C., 1996. A study on the effects of fish (Crustacea/Molluscs) traps on benthic habitats and species. *Final report to the European Commission. Study Contract*, no. 94/076.

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.

Faganeli, J., Av□in, A., Fanuko, N., Malej, A., Turk, V., Tušnik, P., Vrišer, B. & Vukovi□, A., 1985. Bottom layer anoxia in the central part of the Gulf of Trieste in the late summer of 1983. *Marine Pollution Bulletin*, **16**(2), 75-78.

Feldman, K.L., Armstrong, D.A., Dumbauld, B.R., DeWitt, T.H. & Doty, D.C., 2000. Oysters, crabs, and burrowing shrimp: review of an environmental conflict over aquatic resources and pesticide use in Washington State's (USA) coastal estuaries. *Estuaries*, **23**, 141-176.

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

Gage, J.D., 1990. Skeletal growth bands in brittle stars: Microstructure and significance as age markers. *Journal of the Marine Biological Association of the United Kingdom*, **70**, 209-224.

Gibson, F.A., 1956. Escallops (*Pecten maximus* L.) in Irish waters. *Scientific Proceedings of the Royal Dublin Society*, **27**, 253-271.

Gili, J-M. & Hughes, R.G., 1995. The ecology of marine benthic hydroids. *Oceanography and Marine Biology: an Annual Review*, **33**, 351-426.

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

Glémarec, M., 1979. Problemes d'ecologie dynamique et de succession en baie de Concarneau. *Vie et Milieu*, **28-29**, 1-20.

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.

Groenewold, S. & Fonds, M., 2000. Effects on benthic scavengers of discards and damaged benthos produced by the beam-trawl fishery in the southern North Sea. *ICES Journal of Marine Science*, **57** (5), 1395-1406.

Gruffydd, Ll.D., 1974. The influence of certain environmental factors on the maximum length of the scallop, *Pecten maximus* L. *Journal du Conseil International pour l'Exploration de la Mer*, **35**, 300-302.

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

Havenhand, J. & Svane, I., 1989. Larval behaviour, recruitment, and the role of adult attraction in *Ascidia mentula* O. F. Mueller: *Reproduction, genetics and distributions of marine organisms. 23rd European Marine Biology Symposium*. Olsen and Olsen, 127-132.

Hayward, P.J. & Ryland, J.S. 1990. *The marine fauna of the British Isles and north-west Europe*. Oxford: Oxford University Press.

Hayward, P.J. & Ryland, J.S. 1994. *The marine fauna of the British Isles and north-west Europe. Volume 1. Introduction and Protozoans to Arthropods*. Oxford: Clarendon Press.

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. & Hoare, R., 1975. The ecology of sublittoral communities at Abereiddy Quarry, Pembrokeshire. *Journal of the Marine Biological Association of the United Kingdom*, **55** (4), 833-864.

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.

Howell, T.R.W & Fraser, D.I., 1984. Observations on the dispersal and mortality of the scallop *Pecten maximus* (L.). *ICES Council Meeting Papers*, K: 35.

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.*

Hughes, D.J. & Atkinson, R.J.A., 1997. A towed video survey of megafaunal bioturbation in the north-eastern Irish Sea. *Journal of the Marine Biological Association of the United Kingdom*, **77**, 635-653.

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

Hughes, R.G., 1977. Aspects of the biology and life-history of *Nemertesia antennina* (L.) (Hydrozoa: Plumulariidae). *Journal of the*

Marine Biological Association of the United Kingdom, **57**, 641-657.

Hughes, R.G., 1977. Aspects of the biology and life-history of *Nemertesia antennina* (L.) (Hydrozoa: Plumulariidae). *Journal of the Marine Biological Association of the United Kingdom*, **57**, 641-657.

Jenkins, S.R., Beukers-Stewart, B.D. & Brand, A.R., 2001. Impact of scallop dredging on benthic megafauna: a comparison of damage levels in captured and non-captured organisms. *Marine Ecology Progress Series*, **215**, 297-301.

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

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

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

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

Josefson, A.B. & Smith, S., 1984. Changes of benthos-biomass in the Skagerrak-Kattegat during the 70s: a result of chance events, climatic changes or eutrophication? *Meddelande fran Havsfiskelaboratoriet. Lysekil*, **292**, 111-121.

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.*

Kocak, F. & Kucuksezgin, F., 2000. Sessile fouling organisms and environmental parameters in the marinas of the Turkish Aegean coast. *Indian journal of marine sciences*, **29** (2), 149-157.

Laing, I., 2002. Effect of salinity on growth and survival of king scallop spat (*Pecten maximus*). *Aquaculture*, **205**, 171-181.

Last, K.S., Hendrick V. J, Beveridge C. M & Davies A. J, 2011. Measuring the effects of suspended particulate matter and smothering on the behaviour, growth and survival of key species found in areas associated with aggregate dredging. *Report for the Marine Aggregate Levy Sustainability Fund*,

Lorrain, A., Paulet, Y-M., Chauvaud, L., Savoye, N., N&#233zan, E. & Gu&#233rin, L., 2000. Growth anomalies in *Pecten maximus* from coastal waters (Bay of Brest, France): relationship with diatom blooms. *Journal of the Marine Biological Association of the United Kingdom*, **80**, 667-673.

Marshall, C.E. & Wilson, E. 2008. *Pecten maximus* Great scallop. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: http://www.marlin.ac.uk/species/detail/1398

Mason, J., 1983. *Scallop and queen fisheries in the British Isles.* Farnham: Fishing News Books

Mazouni, N., Gaertner, J. & Deslous-Paoli, J.-M., 2001. Composition of biofouling communities on suspended oyster cultures: an *in situ* study of their interactions with the water column. *Marine Ecology Progress Series*, **214**, 93-102.

McGladdery, Bower, S.M, & Rodman, G.G., 2006. Diseases and parasites of scallops. In *Scallops: Biology, Ecology and Aquaculture*, S.E. Shumway & G.J. Parsons (eds), pp. 595-650. Amsterdam, Elsevier.

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.

Mortensen, T.H., 1927. *Handbook of the echinoderms of the British Isles.* London: Humphrey Milford, Oxford University Press.

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.

Muus, K., 1981. Density and growth of juvenile *Amphiura filiformis* (Ophiuroidea) in the Oresund. *Ophelia*, **20**, 153-168.

Naranjo, S.A., Carballo, J.L., & Garcia-Gomez, J.C., 1996. Effects of environmental stress on ascidian populations in Algeciras Bay (southern Spain). Possible marine bioindicators? *Marine Ecology Progress Series*, **144** (1), 119-131.

O'Connor, B., Bowmer, T. & Grehan, A., 1983. Long-term assessment of the population dynamics of *Amphiura filiformis* (Echinodermata: Ophiuroidea) in Galway Bay (west coast of Ireland). *Marine Biology*, **75**, 279-286.

O'Connor, B., Bowmer, T., McGrath, D. & Raine, R., 1986. Energy flow through an *Amphiura filiformis* (Ophiuroidea: Echinodermata) in Galway Bay, west coast of Ireland: a preliminary investigation. *Ophelia*, **26**, 351-357.

O'Reilly, S.S., Hryniewicz, K., Little, C.T.S., Monteys, X., Szpak, M.T., Murphy, B.T., Jordan, S.F., Allen, C.C.R. & Kelleher, B.P., 2014.

Shallow water methane-derived authigenic carbonate mounds at the Codling Fault Zone, western Irish Sea. *Marine Geology*, **357**, 139-150. https://doi.org/10.1016/j.margeo.2014.08.007

Olsen, R.R., 1985. The consequences of short-distance larval dispersal in a sessile marine invertebrate. *Ecology*, **66**, 30-39.

Olsgard, F. & Gray, J.S., 1995. A comprehensive analysis of the effects of offshore oil and gas exploration and production on the benthic communities of the Norwegian continental shelf. *Marine Ecology Progress Series*, **122**, 277-306.

Pagett, R.M., 1980. Tolerance to brackish water by ophiuroids with special reference to a Scottish sea loch, Loch Etive. In *Echinoderms: Past and Present* (ed. M. Jangoux), pp. 223-229. Rotterdam: Balkema.

Palerud, R., Gulliksen, B., Brattegard, T., Sneli, J.-A. & Vader, W., 2004. The marine macro-organisms in Svalbard waters. A catalogue of the terrestrial and marine animals of Svalbard. *Norsk Polarinstitutt Skrifter*, **201**, 5-56.

Paulet, Y.M., Lucas, A. & Gerard, A., 1988. Reproduction and larval development in two *Pecten maximus* (L.) populations from Brittany. *Journal of Experimental Marine Biology and Ecology*, **119**, 145-156.

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

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

Ramsay, K., Kaiser, M.J. & Hughes, R.N. 1998. The responses of benthic scavengers to fishing disturbance by towed gears in different habitats. *Journal of Experimental Marine Biology and Ecology*, **224**, 73-89.

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

Reitan, K.I., Oie, G., Vadstein, O. & Reinertsen, H., 2002. Response on scallop culture to enhanced nutrient supply by experimental fertilization of a landlocked bay. *Hydrobiologia*, **484**, 111-120.

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.

Rosenberg, R., Gray, J.S., Josefson, A.B. & Pearson, T.H., 1987. Petersen's benthic stations revisited. II. Is the Oslofjord and eastern Skagerrak enriched? *Journal of Experimental Marine Biology and Ecology*, **105**, 219-251.

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

Round, F.E., Sloane, J.F., Ebling, F.J. & Kitching, J.A., 1961. The ecology of Lough Ine. X. The hydroid *Sertularia operculata* (L.) and its associated flora and fauna: effects of transference to sheltered water. *Journal of Ecology*, **49**, 617-629.

Rowden, A.A., Jones, M.B. & Morris, A.W., 1998. The role of *Callianassa subterranea* (Montagu) (Thalassinidea) in sediment resuspension in the North Sea. *Continental Shelf Research*, **18**, 1365-1380.

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.

Russell, M., 2013. Echinoderm Responses to Variation in Salinity. *Advances in Marine Biology*, **66**, 171-212.

Rygg, B., 1985. Effect of sediment copper on benthic fauna. *Marine Ecology Progress Series*, **25**, 83-89.

Sagasti, A., Schaffner, L.C. & Duffy, J.E., 2000. Epifaunal communities thrive in an estuary with hypoxic episodes. *Estuaries*, **23**, 474-487.

Sebens, K.P., 1985. Community ecology of vertical rock walls in the Gulf of Maine: small-scale processes and alternative community states. In *The Ecology of Rocky Coasts: essays presented to J.R. Lewis, D.Sc.* (ed. P.G. Moore & R. Seed), pp. 346-371. London: Hodder & Stoughton Ltd.

Sebens, K.P., 1986. Spatial relationships among encrusting marine organisms in the New England subtidal zone. *Ecological Monographs*, **56**, 73-96.

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.

Sinclair, M., Mohn, R.K., Robert, G. & Roddick, D.L., 1985. Considerations for the effective management of Atlantic scallops. *Canadian Technical Report of Fisheries and Aquatic Sciences*, no. 1382.

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.

Stickle, W.B. & Diehl, W.J., 1987. Effects of salinity on echinoderms. In *Echinoderm Studies, Vol. 2* (ed. M. Jangoux & J.M. Lawrence), pp. 235-285. A.A. Balkema: Rotterdam.

Szostek C.L., Davies A.J. & Hinz H., 2013. Effects of elevated levels of suspended particulate matter and burial on juvenile king scallops *Pecten maximus. Marine Ecology Progress Series*, **474**, 155-165.

Theede, H., Ponat, A., Hiroki, K. & Schlieper, C., 1969. Studies on the resistance of marine bottom invertebrates to oxygen-deficiency and hydrogen sulphide. *Marine Biology*, **2**, 325-337.

Thrush, S.F., 1986. Community structure on the floor of a sea-lough: are large epibenthic predators important? *Journal of Experimental Marine Biology and Ecology*, **104**, 171-183.

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.

Tyler, P.A., 1977a. Seasonal variation and ecology of gametogenesis in the genus *Ophiura* (Ophiuroidea: Echinodermata) from the Bristol Channel. *Journal of Experimental Marine Biology and Ecology*, **30**, 185-197.

Vaquer-Sunyer, R. & Duarte, C.M., 2008. Thresholds of hypoxia for marine biodiversity. *Proceedings of the National Academy of Sciences*, **105** (40), 15452-15457.

Vistisen, B. & Vismann, B., 1997. Tolerance to low oxygen and sulfide in *Amphiura filiformis* and *Ophiura albida* (Echinodermata: Ophiuroidea). *Marine Biology*, **128**, 241-246.

Whomersley, P., Wilson, C.M., Clements, A., Brown, C., Long, D., Leslie, A. & Limpenny, D., 2010b. Understanding the marine environment - seabed habitat investigations of submarine structures in the mid Irish Sea and Solan Bank Area of Search (AoS). *Joint Nature Conservation Committee, JNCC Report no.* 430., Peterborough, 128 pp.

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.

Wilson, W.H., 1991. Competition and predation in marine soft sediment communities. *Annual Review of Ecology and Systematics*, **21**, 221-241.

Witt, J., Schroeder, A., Knust, R. & Arntz, W.E., 2004. The impact of harbour sludge disposal on benthic macrofauna communities in the Weser estuary. *Helgoland Marine Research*, **58** (2), 117-128.

Wolff, W.J., 1968. The Echinodermata of the estuarine region of the rivers Rhine, Meuse and Scheldt, with a list of species occurring in the coastal waters of the Netherlands. *The Netherlands Journal of Sea Research*, **4**, 59-85.

Wood, H.L., Spicer, J.I., Lowe, D.M. & Widdicombe, S., 2010. Interaction of ocean acidification and temperature; the high cost of survival in the brittlestar *Ophiura ophiura*. *Marine Biology*, **10**, 2001-2013.

Young, C.M., 1986. Direct observations of field swimming behaviour in larvae of the colonial ascidian *Ecteinascidia turbinata*. *Bulletin of Marine Science*, **39** (2), 279-289.