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Seeps and vents in sublittoral sediments

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

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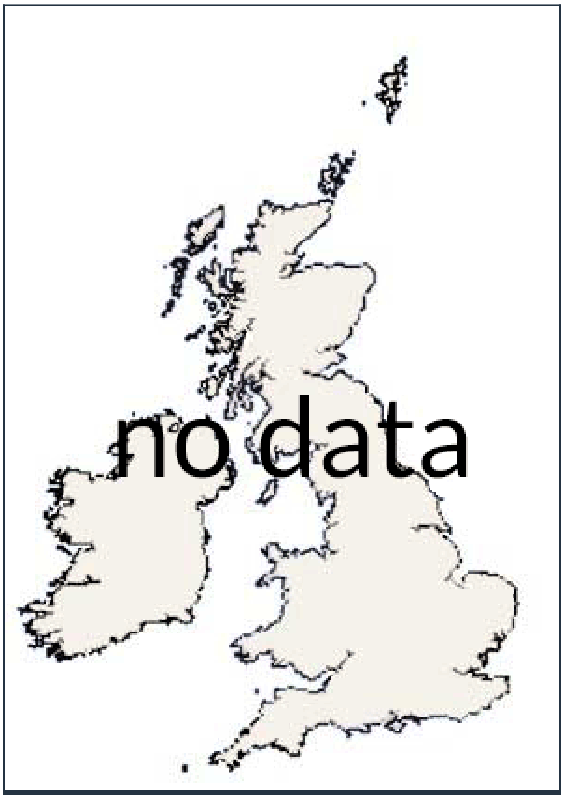

Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

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Summary

UK and Ireland classification

EUNIS 2008	A5.71 Seeps and vents in sublittoral sediments
JNCC 2015	A5.71 Seeps and vents in sublittoral sediments
JNCC 2004	
1997 Biotope	

Description

Features in sublittoral sediments (<200 m deep) created by gas, brine or groundwater ‘seeps’ or hydrothermal vents. Continuous or episodic releases of methane gas form the majority of such features in UK waters. The rising gases modify the sediment by winnowing away fine sediments and changing its geochemistry. In addition, the microbial oxidation of methane forms carbonate (MDAC, methane-derived authigenic carbonate) within the sediment. The carbonate can cement the sediment to form slabs, pavements, or pillars of hard substrata. Two main varieties of the feature are created, pockmarks in soft sediments and ‘bubbling reefs’.

Pockmarks range from 1 to 1000 m in diameter to 1 to 100 m in depth. In the North Sea they are typically 50-100 m in diameter and 1-3 m deep, but small unitary pockmarks are very small (<5 m) while giant pockmarks may be 500 m across and >20 m deep (Hovland & Judd, 1988; Judd & Hovland, 2007, Webb *et al*., 2009). Pockmarks may be circular or elliptical in shape, may merge or form troughs, or occur in strings of shallow depressions 10-15 m in diameter and extend for several hundred metres (Judd & Hovland, 2007).

Obligate species typical of deep-water (<200 m) seeps and vent are absent. Shallow-water (<200 m) pockmarks are colonized by a subset of the surrounding infauna and, where MDAC occurs, epifauna. Microbes (methane-oxidizing bacteria) dominate close to the seep (gas) outlet. The seeping gas results in circulation of the interstitial water near the gas outlet, increasing oxygen and sulphate penetration and dissolved organic carbon levels in the surrounding sediment, and increasing the abundance of bacteria and deposit feeding meiofauna, dominated by nematodes. Seeps are usually indicated by the presence of mats of sulphide-oxidizing bacteria *Beggiatoa*, *Thiothrix* and *Thioplaca*, and may support its own community of grazing ciliates and nematodes and predatory nematodes. Infauna is often limited by the depth of sediment found within the pockmarks due to the presence of concretions (MDAC) or underlying firm (clay) sediments but is highly variable within pockmarks. Near the outlet, the infauna may be limited to sulphide-tolerant species e.g. *Capitella* sp., and *Thyasira sarsi.* As the distance from the gas outlet increases, the sediment community comes to resemble that of the surrounding sediments.

Where MDAC forms within the area of the seep and is exposed within a pockmark, it is colonized by a diverse filter feeding and passive predatory epifauna such as hydroids, bryozoans, sponges, anthozoans, polychaetes, ophiuroids, and gastropods typical of circalittoral faunal turf communities. In shallow examples, macroalgae (e.g. *Laminaria*) may occur. Sea pens *Virgularia mirabilis* and *Pennatula phosphorea*, and the anemones *Cerianthus lloydii*, *Bolocera tuediae*, *Urticina felina* and *Metridium dianthus* have been recorded on the slopes and vicinity of pockmarks. MDAC also provides niches and overhangs for crabs and squat lobster (e.g. *Munida* sp.) and *Nephrops* may burrow where sediment accumulates. Sponges (e.g. *Cliona*) and bivalves (e.g. *Hiatella*) may burrow into the carbonate (MDAC). Pockmarks host unusual densities of fish and shoals of cod (*Gadus morhua*), ling (*Molva molva*), and Norway haddock (*Sebastes viviparus*) have been recorded in the craters of pockmarks. Wolf-fish *Anarhychus lupus* may be found sheltering in underhangs, and ling and torsk (*Brosme brosme*) have been found in caverns within pockmarks.

'Bubbling reefs' occur when slabs, pavements, and pillars of MDAC deposits are exposed by removal of sediment. In the Kattegat, Denmark, the MDAC forms slabs up to 10 m^2 and 2 m above the sediment with pillars up to 4 m (Jensen *et al*., 1992). In the Irish Sea, extensive areas of MDAC form a continuous cliff 6-8 m high and 500 m long and, with other deposits, covers 500,00 m^2 in Texel II and another 10,000 m^2 in Holden Reef. The carbonate reefs at Holdens Reefs, Texel II and Codling Fault Zone in the Irish Sea may be similar to the 'bubbling reefs' of the Kattegat (Judd *et al*., 2007). As above, the MDAC hosts an epifaunal community typical of sublittoral hard substrata in the surrounding area. However, the epifaunal community is reduced in immediate proximity to seeps gas outlets that penetrate the rock or where gas accumulates in caves within the rock. Some epifauna near the gas outlets are coated in methane-oxidizing bacteria and mats of *Beggiatoa* may form in areas in direct contact with the gas. Burrows created by sponges and *Hiatella* provide additional niches for colonization. In the Kattegat, shallow examples are colonized by macroalgae (*Laminaria* sp., *Corallina officinalis* and *Lithothamnion* spp.) and pillars by fouling communities including *Mytilus edulis.* In the mid-Irish Sea, scour resistant species (e.g. *Flustra foliacea* and *Urticina spp.*) dominated the typical fauna in areas close to or covered by mobile sediment and *Sabellaria spinulosa* formed a significant part of the MDAC epifauna in some samples (Whomersley *et al*., 2010b). Description derived from (Dando *et al*., 1991; Dando & Hovland, 1992; Jensen *et al*., 1992; Hovland & Judd, 1988; Dando, 2001; Judd & Hovland, 2007, Judd *et al*., 2007; Webb *et al*., 2009;

Dando, 2010; Whomersley *et al.*, 2010b; O'Reilly *et al.*, 2014).

Depth range

0-5 m, 5-10 m, 10-20 m, 20-30 m, 30-50 m, 50-100 m, 100-200 m

Additional information

Please note, submarine brine and hydrothermal vents are included within this biotope definition but do not occur within UK waters and not mentioned further. Groundwater seeps are probably present in UK water (e.g on the North Wales coast) but their locations are not pinpointed and they have not been the object of study in the UK (Dando, pers. comm.). Therefore, groundwater seeps are also excluded from the current review.

Listed By

- none -

Further information sources

Search on:

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Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

Seeping gases modify the local sediment and its chemistry. Pockmarks form in areas of soft sediment where gas flow is adequate to winnow away fine sediment and develop hollows, pits, or troughs of various sizes and densities. Microbial oxidation of methane from gas seeps forms carbonate within the sediment. The resultant methane-derived authigenic carbonate (MDAC) cements the sediment together to form slabs and pavement (and occasionally pillars) of carbonate. Areas of MDAC range from small boulders at the base of pockmarks to extensive reefs of carbonate. As a result, pockmarks, MDAC, carbonate reefs, and 'bubbling reefs' create ‘oases’ of diversity in otherwise sedimentary habitats (Hovland & Judd, 1988; Judd & Hovland, 2007; Webb *et al.*, 2009; Dando, 2010). Even in the absence of MDAC, seeps and pockmarks increase diversity by changing the microbial, meiofaunal and macrofaunal communities within the sediment. Therefore, the presence of active or episodic methane gas seeps is vital for the formation of these habitats. If a seep becomes inactive, a pockmark is likely to infill over time with fine sediment typical of the surrounding area but remain a refuge or shelter for fish (Dando, 2010). Inactive, ‘Bubbling reefs’ will retain their epifaunal communities but lose the abundance of methane-oxidising and sulphide-reducing microbes, bacterial mats, and their dependent meiofauna, although the biomass and abundance of meiofauna and macrofauna typical of the surrounding sediment will increase.

In contrast to deep-water (>200 m) cold seeps, seep obligate species are absent generally from shallow-water (<200 m) cold seeps and hydrothermal vents and the fauna is generally considered to be a subset of the surrounding fauna (Dando, 2010). For example, only three of 284 macroinfaunal species recorded from North Sea pockmarks contained symbionts (Dando, 2001; 2010). At shallow-water seeps, the infauna shows a pattern of species exclusion compared to the surrounding sediment due to changes in sediment type, limited burrowing depth due to sub-bottom concretions (e.g. clay), lower oxygen penetration, and sulphide toxicity (Dando *et al.*, 1993; Dando, 2010). The microbial and meiofaunal communities and bacterial mat-forming species are probably ubiquitous. Where hard substratum (MDAC) is present, the epifaunal community probably represents similar sublittoral rock faunal communities in the surrounding area. Epifaunal communities are dominated by filter and suspension feeders and passive predators that are dependent on suspended particulates, microbes, phytoplankton and zooplankton. In addition, the majority of the shallow-water seep fauna derive their nutrition from the photosynthetic food chain and the fossil carbon (via chemosynthesis) makes a limited contribution to the food chain (Dando, 2010). The number of chemoautotrophic species decreases significantly with decreasing water depth (Judd & Hovland, 2007).

Judd & Hovland (2007) suggested that majority of scavengers and predators were ‘vagrants’. Mobile scavengers (e.g. starfish and crustaceans) probably utilise the available habitat. However, they would move to other habitats if the pockmark or MDAC was lost or covered. Unusual densities of fish are associated with pockmarks (Hovland & Judd, 1988; Judd & Hovland, 2007; Dando, 2001, 2010). However, the fish most likely use pockmarks and MDAC structures for shelter and forage elsewhere, as fish are also attracted to artificial structures and even to depressions on the seabed (Dando, 2001, 2010).

Physical processes (gas seeps) determine the size, shape and density of the pockmarks in soft sediments are alter the sediment type and chemistry, which in turn alter the communities found. The presence of MDAC in pockmarks adds hard substrata that can be colonized by epifauna. However, loss of the MDAC and its epifauna will not result in loss of the habitat (i.e. the pockmark), although it will decrease its biodiversity. Activities that mobilize sediment may result in temporary loss of the pockmark while activities that interrupt or affect gas flow may result in loss of the pockmarks. Therefore, sensitivity assessment of pockmarks focuses on the physical habitat and discusses the infauna and epifauna where relevant. However, mobile species (e.g. starfish, crustaceans and fish) are probably vagrants or ubiquitous and their abundance or presence within this habitat (or biotope) is not relevant to the sensitivity of the habitat.

‘Bubbling reefs’ are formed by MDAC deposits that are exposed by the erosion of sediments. They are dominated by epifauna and burrowing sponges and molluscs but also host methane-oxidizing bacteria and archaea, and bacterial mats. ‘Bubbling reefs’ are defined by the presence of active seeps and activities that interrupt or affect gas flow may result in loss of the ‘bubbling reef’ although the carbonate reef will remain. However, they host a diverse epifauna dependent on their surrounding area and depth. Therefore, sensitivity assessment for 'bubbling reefs' focuses on the physical habitat and discusses the infauna and epifauna where relevant. However, mobile species (e.g. starfish, crustaceans and fish) are probably vagrants or ubiquitous and their abundance or presence within this habitat (or biotope) is not relevant to the sensitivity of the habitat.

Please note. The resistance, resilience and, hence, sensitivity assessments may vary with habitat, that is, between pockmarks and MDAC structures, and the **explanatory text for each assessment must be consulted** before use.

Resilience and recovery rates of habitat

Pockmarks are predominantly infaunal sedimentary habitats, although the presence of MDAC provides additional habitat for epifauna. The infauna is considered to be a subset of the surrounding infauna and sedimentary epifauna (Judd & Hovland, 2007; Dando, 2010). ‘Bubbling reef’ are predominately epifaunal communities, similar to those that occur in subtidal rocky reefs within the surrounding area, depending on depth and the degree of scour (Jensen *et al*., 1992; Webb *et al*., 2009; Whomersley *et al*., 2010; O’Reilly *et al*., 2014). No specific information on the recovery and recolonization of the infaunal or epifaunal communities of shallow-water (<200 m) cold seeps or ‘bubbling’ reefs was found. Recolonization rates are probably similar to those for similar sediment and hard substrata in the subtidal. However, the exact species present will probably vary between sites, therefore a range of examples are given based on species identified in pockmarks and MDAC communities in the North Sea and Irish Sea (Dando *et al*., 1991; Jensen *et al*., 1992; Dando, 2001; Judd & Hovland, 2007; Webb *et al*., 2009; Dando, 2010; Whomersley *et al*., 2010; O’Reilly *et al*., 2014).

Example sedimentary infauna and epifauna

Capitella capitata is a classic opportunist species possessing life history traits of rapid development, many reproductions per year, high recruitment and high death rates (Grassle & Grassle, 1974; McCall, 1977). Experimental studies using defaunated sediments have shown that on small scales *Capitella* can recolonize to background densities within 12 days (Grassle & Grassle, 1974; McCall, 1977). In Burry Inlet, Wales, tractor towed cockle harvesting led to a reduction in density of some species but *Capitella capitata* had almost trebled its abundance within the 56 days in a clean sandy area (Ferns *et al*., 2000). In favorable conditions, maturity can be reached in <3 months and growth rate is estimated to be 3 cm per year. Adult potential dispersal is up to 1 km. The species complex displays reproductive variability and planktonic larvae are able to colonize newly disturbed patches but after settlement the species can produce benthic larvae brooded within the adult tube to rapidly increase the population before displacement by more competitive species (Gray, 1979). Bolam & Fernandes (2002) and Shull (1997) noted that *Capitella capitata* can colonize azoic sediments rapidly in relatively high numbers. Shull (1997) also demonstrated that this occurs by larval settlement, bedload transport and by burrowing. Thus, when conditions are suitable, the time for the community to reach maturity is likely to be less than six months.

Levinsenia gracilis tends to be found in deep water so little is known about the species. *Levinsenia gracialis* is a polychaete of the small Paraonidae family, which are known to be gonochoric. Larvae have been found in the plankton with up to 60 segments (Bhaud, 1983, cited in Rouse & Pleijel, 2001). This family is found in almost all deep-water regions of the world, and are only found on the surface of sandy or silty sediments or burrowing into the deeper layers of such sediments. Individuals tend to be non-selective surface or burrowing deposit feeders (Rouse & Pleijel, 2001). *Heteromastus filiformis* is a medium-sized tube-dwelling polychaete belonging to the family Capitellidae. The body length is about 10 cm and the worm lives in a vertical tube extending to a depth of about 15 cm into muddy sands (Shaffer, 1983). *Heteromastus filiformis* has a lifespan of 2 years and reproduces once within 2 years. Several authors (cited in Shaffer, 1983) have suggested that it reproduces in spring. Lo Bianco (1909) in Italy and Fauvel (1927) in France reported that breeding and spawning occurred from September to April. Linke (1939), in the Bay of Jadebusen, Germany and Rasmussen (1956) in the Isefjord, Denmark both observed spawning in spring. Cazaux (1970) reported breeding and spawning in the early summer in the Bay of Arcahon, France. In the North Atlantic Ocean to the North Sea, recruitment also appears to be in spring (Gillet & Gorman, 2002). After spawning, the eggs are fertilized externally and released as a planktotrophic larva that spends up to 4 months in the plankton (Shaffer, 1983). Settlement is generally from April-May. Little is known of the fecundity of this genus. The planktonic larval phase allows significant recolonization from surrounding deposits, and the short lifespan allows relatively rapid restoration of biomass following colonization. Buchanan & Warwick (1974) concluded that *Heteromastus filiformis* spawned at the end of its second year, sometime between January and April, off the coast of England, followed by high mortality. Predators have a large effect on the mortality rate of *Heteromastus* juveniles, but not on the adults, and disturbance has a moderate effect on juvenile mortality (Shaffer, 1983). No information regarding the longevity and life cycle of *Paramphionome jeffreysii* was found. *Paramphionome jeffreysii* is a polychaete of the Amphimonidae sub-family, which mainly occur in warm littoral waters. The group is known to be gonochoric with external fertilization. As far as it is known, the group are slow active predators, mainly on sessile animals, such as sponges, cnidarians, hydroids, and ascidians (Rouse & Pleijel, 2001).

Longer lived species that may represent a more developed and stable assemblage include the polychaete *Glycera* spp. *Glycera* spp. are monotelic having a single breeding period towards the end of their life but may recover through migration and may persist in disturbed sediments through their ability to burrow (Klawe & Dickie, 1957). *Glycera* spp. have a high potential rate of recolonization of sediments, but the relatively slow growth-rate and long lifespan suggest that recovery of biomass following initial recolonization by post-larvae is likely to take several years (MES, 2010). Population recovery was tracked by Sardá *et al.* (2000) following dredging of subtidal sands in summer and autumn to provide material for beach nourishment in the Bay of Blanes, (north-west Mediterranean sea, Spain). Recolonization in the dredged habitats was rapid, with high densities of *Spisula subtruncata* , although most of these recruits did not survive summer. However, Glycera spp. had not recovered within two years (Sardá *et al.*, 2000).

Little information was available for *Thyasira flexuosa*. The larval development of the congener *Thyasira equalis* is lecithotrophic and the pelagic stage is very short or suppressed (Tillin & Tyler-Walters, 2014). This agrees with the reproduction of other *Thyasira* sp., and in some cases (e.g. *Thyasira gouldi*) no pelagic stage occurs at all (Thorson, 1946, 1950). This means that larval dispersal is limited. Sparks-McConkey & Watling (2001) found that a population of *Thyasira flexuosa* in Penobscot Bay, Maine recovered rapidly (within 3.5 months) following trawler disturbance that resulted in a decrease in the population. Benthic reproduction allows recolonization of nearby disturbed sediment and leads to rapid recovery where a large proportion of the population remains to repopulate the habitat.

Little is known about the life history and population dynamics of sea pens (Hughes, 1998a). 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). However, no information on larval development, settlement behaviour, or dispersal was found. 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, 2009). Large oocytes suggested a long-lived lecithotrophic larval stage that may result in a relatively long period of time in the water column and high potential dispersal ability and may explain the high gene flow observed between colonies of *Funiculina quadrangularis* in two Scottish sea lochs (Wright *et al.*, 2015). Wright *et al.* (2015) found limited genetic population subdivision within and between populations of *Funiculina quadrangularis* in Loch Linnhe and Loch Duich. The high genetic diversity and unique genotypes supported the absence of asexual reproduction in this species (Wright et al., 2015). No similar studies were available for *Virgularia mirabilis*, but Edwards & Moore (2009) noted that many sea pens exhibited similar characteristics.

Experimental colonization studies in a deep-water seep on the Calfiornian margin, Pacific, demonstrated rapid colonization of exerpimental trays of sediment, with or without sulphide (Levin *et al.*, 2006). Annelids comporised the topfive or the top ten colonistrs. Polychaetes such as *Mediomastus* spp, and *Aphelochaeta* sp., Paraonidae and Nerillidae exhibited higher densities in treatments with sulphide. Overall, the experimental trays exhibited some but not all of the characteristics of ambient seep assemblages within 6 months, although the experiment was only run for 6 months (Levin *et al.*, 2006).

Overall, recolonization of the infauna of pockmarks will occur from the surrounding sediments. Microbes and meiofauna (e.g. nematodes) are probably ubiquitous and reproduce rapidly and likely to remain in the sediment even after disturbance. Bivalves *Kurtiella bidentata, Abra nitida, Thyasira spp.*, have fragile shells that are vulnerable to damage, are thought to be slow growing, have a high dispersal potential but recruitment tends to be sporadic. The polychaete species, including *Levinsenia gracilis, Heteromastus filiformis* and *Paramphinome jeffreysii* are often characterized by short lifespans and likely to have high recovery rates. So where the majority of the population remain (resistance is 'High' or 'Medium'), and/or recruitment by adult mobility is possible, resilience is likely to be **'High'**. However, where recovery through juvenile recruitment is required, this may be low in places and are dependent on favourable hydrodynamic conditions that allow settlement of new recruits. Although polychaetes tend to have high recovery rates, the low energy environments where the biotopes occur are likely to slow the time for most species to re-established biomass and age structured populations. Therefore, where impacts remove a significant proportion of the population (resistance is 'Low' or 'None'), recovery is likely to be

'Medium' (2-10 years). Sea pens and large anemones may take longer to recolonize due to slow growth and sporadic, patchy, recruitment. However, recognizable 'pockmark' communities will probably re-establish beforehand. Given that no information was found for some of the characterizing species of these biotopes, confidence in this assessment is 'Low'.

Example hard substratum epifauna

Hydroids are often the first organisms to colonize available space in settlement experiments and fouling communities (Standing, 1976; Brault & Bourget, 1985; Sebens, 1986; Jensen *et al*., 1994; Gili & Hughes, 1995; Hatcher, 1998). For example, the hydroids *Aglaophenia plumosa* and Sertularia argentea lack a medusa stage, releasing planula larvae (Cornelius, 1995b). Planula larvae swim or crawl for short periods (e.g. <24hrs) so that dispersal away from the parent colony is probably very limited (Sommer, 1992; Gili & Hughes, 1995). *Tubularia indivisa* releases a slow crawling actinula larvae with potentially very limited dispersive range (Fish & Fish, 1996). However, *Nemertesia antennina* releases planulae on mucus threads, that increase potential dispersal to 5 -50m, depending on currents and turbulence (Hughes, 1977). In settlement experiments, the hydroids *Cordylophora caspia*, *Obelia dichotoma* and *Obelia longissima* colonized artificial substrata within ca 1-3 months of deployment (Standing, 1976; Brault & Bourget, 1985: Sandrock *et al*., 1991). Similarly, Hatcher (1998) reported that *Tubularia larynx* colonized settlement panels within only 68 days (ca 2 months). Once colonized the hydroids ability to grow rapidly and reproduce asexually is likely to allow them to occupy space and sexually reproduce quickly.

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). 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 allows hydroids to colonize space rapidly. Fragmentation may also provide another route for short distance dispersal. However, it has been suggested that 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 allow 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).

The brooded, lecithotrophic coronate larvae of many bryozoans (e.g. *Flustra foliacea*, *Securiflustra securifrons*, and *Bugula* (and *Bugulina*) species), have a short pelagic lifetime of several hours to about 12 hours (Ryland, 1976). Recruitment is dependent on the supply of suitable, stable, hard substrata (Eggleston, 1972b; Ryland, 1976; Dyrynda, 1994). However, even in the presence of available substratum Ryland (1976) noted that significant recruitment in bryozoans only occurred in the proximity of breeding colonies. For example, Hatcher (1998) reported colonization of slabs, suspended 1 m above the sediment, by *Bugulina fulva* within 363 days while Castric-Fey (1974) noted that *Bugulina turbinata* and *Bugulina calathus* did not recruit to settlement plates after ca two years in the subtidal even though present on the surrounding bedrock. Similarly, Keough & Chernoff (1987) noted that *Bugula neritina* was absent from areas of seagrass bed in Florida even though substantial populations were present <100 m away.

Echinoderms are highly fecund, producing long-lived planktonic larvae with high dispersal potential. However, recruitment in echinoderms is poorly understood, often sporadic and variable between locations and dependant on environmental conditions such as temperature, water quality and food availability. For example, in *Echinus esculentus* recruitment was sporadic and Millport populations showed annual recruitment, whereas few recruits were found in Plymouth populations between 1980-1981 (Nichols, 1984). Bishop & Earll (1984) suggested that the population of *Echinus esculentus* at St Abbs had a high density and recruited regularly whereas the Skomer population was sparse, ageing and had probably not successfully recruited larvae in the previous 6 years. However, echinoderms such as *Echinus esculentus*, and *Asterias rubens* are mobile and widespread and are likely to recruit be migration from other areas.

Sponges may proliferate both asexually and sexually. A sponge can regenerate from a broken fragment, produce buds either internally or externally or release clusters of cells known as gemmules which develop into a new sponge, depending on species. Most sponges are hermaphroditic but cross-fertilization normally occurs. The process may be oviparous, where there is a mass spawning of gametes through the osculum which enter a neighbouring individual in the inhalant current. Fertilized eggs are discharged into the sea where they develop into a planula larva. However, in the majority development is viviparous, whereby the larva develops within the sponge and is then released. Larvae have a short planktonic life of a few hours to a few weeks, so that dispersal is probably limited and asexual reproduction probably results in clusters of individuals.

Anthozoans, such as *Alcyonium digitatum* is long lived with potentially highly dispersive pelagic larvae and are relatively widespread. They are not restricted to this biotope and would probably be able to recruit within 2-5 years (Sebens, 1985; Jensen *et al.*, 1994). Juvenile anthozoans are susceptible to predation by sea urchins or overgrowth by ascidians (Sebens, 1985; 1986). Ascidians such as *Molgula manhattensis* and *Clavelina lepadiformis* have external fertilization but short-lived larvae (swimming for only a few hours) so that dispersal is probably limited (see MarLIN reviews). Where neighbouring populations are present, recruitment may be rapid but recruitment from distant populations may take a long time. Mobile epifauna will probably recruit from the surrounding area as the community develops and food, niches and refuges become available, either by migration or from planktonic larvae. For example, Hatcher (1998) noted that the number of mobile epifaunal species steady increased over the year following deployment of settlement panels in Poole Harbour.

Recruitment is partly dependant on the availability of free space, provided by grazing, predation, physical disturbance or seasonal die back on some species. The presence of erect species may interfere with recruitment of others, e.g. the dense stands of the hydroid *Obelia longissima* inhibited settlement by *Balanus crenatus* cyprid larvae but encouraged settlement by ascidian larvae (Standing, 1976). In addition, filter feeding hydroids and anthozoans probably take the larvae of many organisms. Once settled the slow-growing species may be overgrown or devoured by predator/grazers, e.g. juvenile *Alcyonium digitatum* are highly susceptible to being smothered or eaten when small but can survive intense sea urchin predation when large (Sebens, 1985, 1986). Overall, rapid growth and reproduction secure space in the community for many species e.g. hydroids and bryozoans while ascidians and Anthozoa are better competitors but more susceptible to predation (Sebens, 1985, 1986).

The recolonization of epifauna on vertical rock walls was investigated by Sebens (1985, 1986). He reported that 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, and, together with *Halichondria panicea*, reached pre-clearance levels of cover after 2 years. A few individuals of

Alcyonium digitatum and *Metridium dianthus* (as *senile*) colonized within 4 years (Sebens, 1986) and would probably take longer to reach pre-clearance levels.

Jensen *et al.* (1994) reported the colonization of an artificial reef in Poole Bay, England. They noted that erect bryozoans, including *Crisularia plumosa*, began to appear within 6 months, reaching a peak in the following summer, 12 months after the reef was constructed. Similarly, ascidians colonized within a few months e.g. *Aplidium* spp. Sponges were slow to establish with only a few species present within 6-12 months but beginning to increase in number after 2 years, while anemones were very slow to colonize with only isolated specimens present after 2 years (Jensen *et al.*, 1994.). In addition, Hatcher (1998) reported a diverse mobile epifauna after a year's deployment of her settlement panels.

Overall, hydroids, bryozoans, and ascidians are opportunistic, grow, and colonize space rapidly and can probably develop a faunal turf within 1-2 years. Mobile epifauna and infauna will probably colonize rapidly from the surrounding area. However, slow growing species such as some sponges and anemones will probably take many years to develop significant cover, so that a diverse community may take up to 5 -10 years to develop, depending on local conditions. Therefore, where resistance is 'Medium' (some mortality), resilience is likely to be '**High**'. However, where resistance is 'Low' or 'None' and the epifaunal community is significantly affected by a pressure, then resilience is probably **Medium** (2-10 years).

Physical habitat

The onset of a new seep has not been witnessed but it is thought that colonization of deep-water seeps would be rapid, as it is in deep-water hydrothermal vents (Lutz *et al.*, 1994; Judd & Hovland, 2007). For example, after a new eruption in the east Pacific, tubeworms populations were established with two years (Lutz *et al.*, 1994). Bowden *et al.* (2013) suggested a succession model for deep-water cold seeps in New Zealand continental margin. They suggested that microbes colonized new gas flows rapidly, and aerobic methanotrophic and thiotrophic microbial communities visible on the surface within 1-10 years. Dense populations of ampharetid polychaetes took between 1 and 100 years, while vesicomyid clams colonize within ca 50 years. If the presence of persistent gas flow, they suggested that MDAC particles form and allow colonization by lamellbrachia tubeworms in ca >100s of years and the carbonate builds-up and eventually caps the site, allowing colonization by a range of non-seep specific epifauna within ca >1000s of years (Bowden *et al.*, 2013).

Judd & Hovland (2007) note that extensive MDAC deposits indicate that methane seeps under the sediment surface have continued for extensive time periods. Whomersely *et al.* (2010) suggested that the MDAC deposits in the mid-Irish Sea (Texel 11) were probably laid in the cooler post glacial period 15-25 thousand years before present (ybp). Bowden *et al.* (2013) reported that carbonate reefs structures in the deep-water of the continental margins of New Zealand ranged in age from 2,090 to 4,390 ybp at the youngest sites to 12,400±160 ybp at the oldest sites, although carbonate formation was ongoing. Therefore, extensive areas of MDAC probably take >1000s of years to develop, and if removed by human activities or erosion are unlikely to return

Pockmarks are maintained by continuous or episodic gas escapes (Judd & Hovland, 2007; Dando, 2010). Therefore, if a pockmark was filled by human activity or storm action (depending on depth) it is likely to recover rapidly as long as the gas seep remains active. Hence, resilience is probably **High** (< 2 years). However, MDAC deposits may takes 100s to 1000s of years to develop. The removal of small boulders is probably permanent. Similarly, any activity that broke up and removed a proportion of the MDAC 'reef' is likely to be permanent. Hence, resilience would be considered '**Very low**'.

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

The infaunal communities of pockmarks in shallow-water (<200 m) are drawn from the surrounding area. Most pockmarks are recorded from north of 56° in the North Sea with high densities in the Witch Ground and Norwegian Trench (Dando 2001; Judd & Hovland, 2007) but are also recorded in western mud belt in the Irish Sea. Judd & Holvand (2007) suggested that seeps (and pockmarks) are likely to be more widespread in the North Sea.

The majority of the species recorded in UK pockmarks are widely distributed around the coasts of the British Isles and to the north and south of the British Isles. Similarly, epifaunal communities on boulders and outcrops of MDAC (methane-derived authigenic carbonate) in pockmarks and extensive areas of MDAC in 'bubbling reefs' are opportunistic species drawn from the surrounding area.

Therefore, the exact infaunal communities present in pockmarks or epifaunal communities present on MDAC (e.g. from the North Sea and the Irish Sea) may vary with latitude but also local hydrography, depth, sediment type and scour. The majority of the species present are widely distributed to the north and south of the British Isles and are unlikely to be affected by chronic changes in temperature, e.g. a change of 2°C. A short-term change of 5°C may interrupt breeding or alter growth rates (depending on season). An increase in temperature may favour more southerly species, while a decrease may favour more northerly species but the character of the habitat is unlikely to be changed and a resistance of **'High'** is recorded. Hence, resilience is also **'High'** and the habitat is probably '**Not sensitive'** at the benchmark level.

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

The infaunal communities of pockmarks in shallow-water (<200 m) are drawn from the surrounding area. Most pockmarks are recorded from north of 56° in the North Sea with high densities in the Witch Ground and Norwegian Trench (Dando 2001; Judd & Hovland, 2007) but are also recorded in western mud belt in the Irish Sea. Judd & Holvand (2007) suggested that seeps (and pockmarks) are likely to be more widespread in the North Sea.

The majority of the species recorded in UK pockmarks are widely distributed around the coasts of the British Isles and to the north and south of the British Isles. Similarly, epifaunal communities on boulders and outcrops of MDAC (methane-derived authigenic carbonate) in pockmarks and extensive areas of MDAC in 'bubbling reefs' are opportunistic species drawn from the surrounding area.

Therefore, the exact infaunal communities present in pockmarks or epifaunal communities present on MDAC (e.g. from the North Sea and the Irish Sea) may vary with latitude but also local hydrography, depth, sediment type and scour. The majority of the species present are widely distributed to the north and south of the British Isles and are unlikely to be affected by chronic changes in temperature, e.g. a change of 2°C. A short-term change of 5°C may interrupt breeding or alter growth rates (depending on season). An increase in temperature may favour more southerly species, while a decrease may favour more northerly species but the character of the habitat is unlikely to be changed and a resistance of **'High'** is recorded. Hence, resilience is also **'High'** and the habitat is probably '**Not sensitive'** at the benchmark level.

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

Pockmarks occur globally between a depth of 6 and 4800 m (Fader, 1991; cited in Webb *et al.*, 2009b). In the North Sea they occur in deep soft sediments (<200 m) in stable fully saline conditions. Reefs of MDAC are recorded from a range of depths, for example from the intertidal and shallow subtidal in the Kattegat (Dando *et al.*, 1994); at 10-12 m in the Kattegat (Jensen *et al.*, 1992); at 6.2-9.5 m at Holden's Reef (Irving *et al.*, 2007); at 60-75 m in the Texel 11 Reefs, and at 50-120 m in the Codling Fault Zone in the Irish Sea (Judd *et al.*, 2007; O'Reilly *et al.*, 2014). Therefore, the resident infauna and epifauna is likely to be adapted to the salinity regime in which the habitat (pockmark or MDAC reef) occurs.

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 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. Hypersaline effluents are likely to be localised but dispersed quickly in areas of strong currents, e.g. Texel 11 in the Irish Sea (Judd, 2005). Therefore, in areas of strong tidal streams or wave action, hypersaline effluents may not have an adverse effect. However, in low energy environments, hypersaline effluents may be detrimental and result in reduced diversity and an impoverished infauna and epifauna in the area of effect. Therefore, a resistance of **'Low'** is suggested. Colonization from the surrounding area is probably rapid but the community may take two or more years to recover and a resilience of '**Medium**' is recorded. Hence, sensitivity is assessed as of '**Medium**'.

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

Pockmarks occur globally between a depth of 6 and 4800 m (Fader, 1991; cited in Webb *et al.*, 2009b). In the North Sea they occur in deep soft sediments (<200 m) in stable fully saline conditions. Reefs of MDAC are recorded from a range of depths, for example from the intertidal and shallow subtidal in the Kattegat (Dando *et al.*, 1994); from 10-12 m in the Kattegat (Jensen *et al.*, 1992); at 6.2-9.5 m at Holden's Reef (Irving *et al.*, 2007); at 60-75 m in the Texel 11 Reefs, and at 50-120 m in the Codling Fault Zone, in the Irish Sea (Judd *et al.*, 2007; O'Reilly *et al.*, 2014). Therefore, the resident infauna and epifaunal is likely to be adapted to the salinity regime in which the habitat (pockmark or MDAC reef) occurs.

A decrease in salinity at the benchmark level, e.g. from full to reduced salinity for a year would probably result in a change in the resident community and a reduction in diversity. If the habitat occurred in variable salinity environments then the community is likely to be more resistant. However, in relatively stenohaline circalittoral habitats then the community is likely to be adversely affected. Therefore, a resistance of **'Low'** is suggested. Colonization from the surrounding area is probably rapid but the community may take two or more years to recover and a resilience of **'Medium'** is recorded. Hence, sensitivity is assessed as '**Medium**'.

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

Pockmark morphology may alter water flow and currents. Increased water flow could lead to increased numbers of suspension feeders while reduced flow increases deposition and hence the abundance of deposit feeders (Dando, 2001; Webb *et al.*, 2009b). Deep pockmarks probably reduce flow and increase the suitability of the habitat to deposit feeders (Dando, 2001). For example, the Scanner pockmark reduces bottom flow within the pockmark, which enhances fill by fine sediment and also retain colder more saline water than the surrounding seabed (Dando, 2001). Visibility in deep pockmarks is often reduced due to high concentrations of suspended particulates that attract swarms of shrimps and euphausids. But in wide and shallow pockmarks the bottom currents may not be altered (Dando, 2001). However, Dando (2001) noted that limited information on flow rates within pockmarks was available.

The epifauna of hard substrata are primarily suspension feeder's dependent water flow to bring food particulates within reach. Webb *et al.* (2009) suggested that the large gorgonian corals found on MDAC with the pockmarks within the Norwegian Channel and abundant sea anemones and sea pens on the pockmark slopes benefited from a rich food supply generated by increased currents and re-suspension of particulates by turbulent currents and/or by active gas seepage.

In the Irish Sea, the MDAC reefs in Texel 11 occur in areas of strong tidal currents and mobile sands (Judd *et al.*, 2007; Whomersely *et al.*, 2010). The effect of burrowing species and currents are causing erosion of the reef into boulders, cobbles and sands. The resident epifaunal community is typical of sand scoured rocky habitats, dominated by *Flustra foliacea* with abundant *Sabellaria spinulosa* (Whomersely *et al.*, 2007).

Sensitivity assessment. The effect of changes in water flow will depend on the habitat. However, there is little information on the water flow regime on which to base an assessment. Decreased water flow is probably detrimental to suspension feeding epifauna that depend on water flow to supply food, where water flow is more important than flow and circulation created by gas seepage. In areas of strong tidal streams and scour, a reduction in flow may reduce scour and allow a more diverse epifaunal community to develop. Therefore, in areas of strong tidal flow, a change in water flow at the benchmark level (0.1-0.2 m/s change for a year) is probably not significant. Therefore, resistance and resilience are considered '**High**' and the biotope assessed as '**Not sensitive'**, at the benchmark level.

However, in soft muddy habitats, a change in water flow at the benchmark level (0.1-0.2 m/s change for a year) may modify and mobilise the fine sediment. A significant increase in water flow may disturb bottom sediments and modify the shape of or fill pockmarks. Croker *et al.* (2005) noted that pockmarks will not remain if seabed erosion occurs. However, the pockmark may be recreated due to continued or episodic gas seepage. Therefore, a resistance of **'Medium'** is recorded to represent the potential change in sediment and the infaunal community. Hence, resilience is probably **'High'** and sensitivity is assessed as **'Low'**, but with 'Low confidence.

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

Not relevant to sublittoral habitats. Emergence is relevant to intertidal examples of MDAC reefs but they are excluded from the definition of this biotope (A5.71).

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

In the North Sea, pockmarks were recorded from 120 -249 m (Hovland & Judd, 1988) and 50-100 m in the Irish Sea (Judd, 2005). Reefs of MDAC are recorded from a range of depths, for example from the intertidal and shallow subtidal in the Kattegat (Dando *et al.*, 1994); at 10-12 m in the Kattegat (Jensen *et al.*, 1992); at 6.2-9.5 m at Holden's Reef (Irving *et al.*, 2007); at 60-75 m in the Texel 11 Reefs, and at 50-120 m in the Codling Fault Zone in the Irish Sea (Judd *et al.*, 2007; O'Reilly *et al.*, 2014).

In UK waters the habitats occur at depths where water movement is determined by tidal currents rather than wave action. Therefore, a change of <5% in significant wave height is unlikely to create a significant change in water movement at the seabed. Therefore, resistance and resilience are considered **'High'** and the habitat 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

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

Pockmarks are naturally organic-rich habitats dominated by infauna adapted to low oxygen, sulphide-rich conditions. Infauna closer to the gas outlet(s) exhibit species exclusion due to sulphide toxicity, lower oxygen penetration, modification of the sediment, together with limited burrowing depth due to sub-bottom concretions (Dando, 2010). Infauna close to gas outlets is dominated by sulphide tolerant species, e.g. *Capitella* spp., and *Thyasira* spp. *Thyasira sarsi* hosts endosymbiotic bacteria from which it derives nutrition. Bacterial mats of sulphur bacteria (*Beggiatoa*, *Thiothrix* and *Thioplaca* spp.) are typical around the gas outlets (Dando & Hovland, 1992; Dando, 2010). The infauna becomes more similar to that of the surrounding sediment with increasing distance from the gas outlet(s). Dando (2001; 2010) also noted that pockmarks act as sediment traps so that even inactive pockmarks will have a higher organic content, and potentially lower oxygen levels than the surrounding sediment.

Epifaunal communities within pockmarks colonize boulders or outcrops of MDAC above the sediment, and in areas of water flow, although the exact water flow regime will vary with the size and depth of the pockmarks and the area of seabed in which it is found. Most epifauna are suspension feeders adapted to water flow, although their tolerance or requirement for water flow varies with species or taxonomic group. For example, Gray *et al.* (2002) concluded that fish were more sensitive to hypoxia that crustacean and echinoderms, which in turn were more sensitive than annelids with molluscs the most tolerant. Riedel *et al.* (2010) noted that infauna were generally more tolerant than epifauna. They also noted that decapods, echinoderms, and polychaetes showed lower tolerance while ascidians and anthozoans showed higher tolerance to hypoxia and anoxia (Riedel *et al.* 2010). Mobile species, such as fish, would probably move away from the affected area.

Sensitivity assessment. The infaunal and microbial communities within pockmarks are adapted to low oxygen conditions and are unlikely to be adversely affected by a reduction in oxygen levels at the benchmark levels. The infauna on the slopes and the surrounding sediment in silty sedimentary areas are also probably adapted to low oxygen conditions. However, epifauna dependent on the MDAC within pockmarks may be adversely affected in areas of low water movement, depending on the species present.

Similarly, epifauna dominating reefs of MDAC in areas of low water movement may be adversely affected. Therefore, it is possible that a proportion of the epifaunal community could be lost due to deoxygenation at the benchmark level and a resistance of **'Medium'** is suggested. Hence, resilience is assessed as **'High'** and sensitivity as '**Low**' but with 'Low' confidence.

Epifaunal communities that occur on exposed MDAC reefs in areas strong water movement (e.g. in the mid-Irish Sea) are unlikely to be adversely affected at the benchmark level. Strong water movement would prevent anything but transient decreases in oxygenation. Therefore, in these habitats, the epifauna communities are considered to have a **'High'** resistance to deoxygenation at the benchmark level. Hence, resilience is also '**High'** and the habitat is likely to be **'Not sensitive**'.

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

Nutrient input from the sediment is significant at shallow-water (<200 m) cold seep habitats (Dando, 2010). Near the gas outlets, shallow sediment re-circulation of water causes organic enrichment by particulate organic carbon (POC) in a zone around the outlet (O'Hara *et al*., 1995); Dando, 2010) which supports deposit and filter feeders, and dilutes the sulphide concentrations. Algal species indicative of eutrophication can be found at shallow examples of seeps (Dando, 2010). Anoxic conditions are typical in the sediment, especially close to the gas outlet(s). In addition, the majority of the shallow-water seep fauna derive their nutrition from the photosynthetic food chain and the fossil carbon (via chemosynthesis) makes a limited contribution to the food chain (Dando, 2010).

Epifauna can live closer to the gas outlet(s) due to the rapid dilution of the seep gases. Epifauna probably benefit from the increased POC and possibly the bacterial biomass resulting from organic enrichment in active seeps. However, evidence on the direct effect of organic or nutrient enrichment on epifauna is limited and effects are probably due to hypoxia and smothering rather than the enrichment itself.

However, nutrient enrichment may have adverse effects on epifaunal communities. Johnston & Roberts (2009) conducted a meta-analysis, which reviewed 216 papers to assess how a variety of contaminants (including sewage and nutrient loading) affected six marine habitats (including subtidal reefs). A 30-50% reduction in species diversity and richness were identified from all habitats exposed to the contaminant types.

Sensitivity assessment. Pockmarks are nutrient enriched habitats. Active 'bubbling reefs' are also likely to exhibit nutrient enrichment in the vicinity of the gas outlets. Therefore, the effect of additional nutrient enrichment will probably depend on the type of habitat (pockmark vs. MDAC) the degree of gas seepage and distance from the gas outlet(s). Extensive reefs that host a diverse epifaunal community may see an increase in green algae in shallow waters or a decrease in species richness. However, the pressure benchmark assumes compliance with good status as defined by the WFD. Therefore, resistance and resilience are assessed as **'High'**, and the habitat is considered to be **'Not sensitive'** at the benchmark level.

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

Nutrient input from the sediment is significant at shallow-water (<200 m) cold seep habitats (Dando, 2010). Near the gas outlets, shallow sediment re-circulation of water causes organic enrichment by particulate organic carbon (POC) in a zone around the outlet (O'Hara *et al*., 1995; Dando, 2010) which supports deposit and filter feeders, and dilutes the sulphide concentrations. Shallow-water seeps communities are typical of reducing sediments rich in organic matter. POC inputs can come from chemosynthetic bacteria, heterotrophic prokaryotes, cyanobacteria, benthic diatoms, photosynthetic plankton and marine and terrestrial plants (Dando, 2010). However, infauna closer to the gas outlet(s) exhibit species exclusion due to sulphide toxicity, lower oxygen penetration, modification of the sediment, together with limited burrowing depth due to sub-bottom concretions (Dando, 2010). Dando (2001; 2010) also noted that pockmarks act as sediment traps so that even inactive pockmarks will have a higher organic content than the surrounding sediment.

Bacterial mats of sulphur bacteria (*Beggiatoa*, *Thiothrix* and *Thioplaca* spp.) are typical around the gas outlets (Dando & Hovland, 1992; Dando, 2010). Infauna close to gas outlets is dominated by sulphide tolerant species, e.g. *Capitella* spp., and *Thyasira* spp. *Thyasira sarsi* hosts endosymbiotic bacteria from which it derives nutrition. Echiurans may also feed on bacterial mats (Dando, 2010). Dando (2010) suggested that chaetopterid polychaetes thrived at vent and seep sites due to the high bacterial biomass they could filter from the water column while avoiding high sulphide concentrations diluted by the water flow through their tubes.

Epifauna can live closer to the gas outlet(s) due to the rapid dilution of the seep gases. Epifauna probably benefit from the increased POC and possibly the bacterial biomass resulting from organic enrichment in active seeps. However, evidence on the direct effect of organic or nutrient enrichment on epifauna is limited and effects are probably due to hypoxia and smothering rather than the enrichment itself.

For example, O'Dea & Okamura (2000) found that annual growth of *Flustra foliacea* in western Europe has substantially increased since 1970. They suggested that this could be due to eutrophication in coastal regions due to organic pollution, leading to increased phytoplankton biomass (see Allen et al., 1998). Koopmans & Wijffels (2008) found no correlation between the growth rate of *Halilcona oculata* and dissolved organic carbon, suggesting that *Haliclona oculata* is more dependent on particulate organic carbon. Rose & Risk (1985) described an increase in abundance of the sponge *Cliona delitrix* in an organically polluted section of Grand Cayman fringing reef affected by the discharge of untreated faecal sewage. Mayer-Pinto & Junqueira (2003) studied the effects of organic pollution on fouling communities in Brazil and found that tolerance of polluted/unpolluted artificial reefs varied among bryozoan species. It should be noted that *Bugula* spp. preferred the polluted sites.

In addition, Johnston & Roberts (2009) conducted a meta-analysis, which reviewed 216 papers to assess how a variety of contaminants (including sewage and nutrient loading) affected six marine habitats (including subtidal reefs). A 30-50% reduction in species diversity and richness were identified from all habitats exposed to the contaminant types.

Sensitivity assessment. Pockmarks are naturally organic-rich habitats dominated by infauna adapted to low oxygen, sulphide-rich conditions. Therefore, infauna within the pockmarks and its slopes are probably unlikely to be affected by organic enrichment at the benchmark level. Hence, resistance is assessed as **'High'**, resilience as **'High'** and sensitivity is assessed as '**Not sensitive'** at the benchmark level.

Epifaunal communities, either on boulders and outcrops within pockmarks or on reefs of MDAC are probably more sensitive to increases in nutrient and organic enrichment. However, the extent of the effect likely depends on the hydrography, the species present, and the background levels of nutrients within that area. Active 'bubbling reefs' are probably organic and nutrient enriched due to the gas seepages. Therefore, a resistance of **'Low'** is suggested to represent the potential loss of species diversity but with 'Low' confidence. Hence, resilience is assessed as **'Medium'** and sensitivity 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

This pressure represents a permanent change in seabed type from sedimentary to hard or hard to sedimentary, e.g. by the addition of rock armour or artificial reefs. A pockmark 'filled' by hard substrata would be lost, although it is assumed that gas could find another route to the surface in the surrounding area. Reefs of MDAC (methane-derived authigenic carbonate) that are replaced with sediment (e.g via prolonged spoil dumping or physical removal) would be lost together with the epifaunal and interstitial community they host. MDAC deposits probably taker 100s or 1000s of years to develop. Therefore, resistance is likely to be **'None'** and permanent loss of habitat means that resilience is **'Very low'** by definition. Hence, sensitivity is assessed as **'High'**. Pockmarks may be lost but remerge in the vicinity if seeping gases find another route through the sediment, however, the pockmark(s) of interest will be lost.

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

This pressure represents a permanent change in sediment type. Pockmarks characterize soft fine sediments (Dando & Hovland, 1992; Dando, 2001). In sandy sediments (e.g. fine to medium sands and silty sand of the Tommeliten field) seeps resulted in small funnels or small eye pockmarks (3-5 m across and 0.5 m deep) (Hovland & Judd, 1988). Therefore, a change in sediment type from mud and sandy muds to muddy sands and sands may result in smaller pockmarks but a change in sediment to coarser gravels dominated sediments may allow gas to escape without forming a pockmark. However, consolidated mixed 'lag' deposit may allow pockmarks to form. Therefore, a change in sediment type may result in loss of pockmark, depending on the sediment present in the affected area, and a resistance of **'Low'** is suggested, albeit with 'Low' confidence.

MDAC forms within the sediment and is exposed in pockmarks or as extensive reefs. Whomersely *et al.* (2010) suggested that the action of boring organisms and currents resulted in the breakdown of the MDAC reefs in the mid-Irish Sea to boulders and eventually sand. The sediment type surrounding refs of MDAC affect the rate of erosion and affect the epifaunal community due to scour. However, a change in sediment type' is technically 'Not relevant' on hard substrata such as MDAC.

Sensitivity assessment. A change is sediment type from fine silty and sandy sediment to coarse sediments may result in loss of the pockmarks and prevent their recovery. Therefore, resistance is assessed as **'Low'** and resilience as **'Very low'** (a permanent change) and sensitivity is assessed as **'High'** but with 'Low' confidence.

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

The physical removal of the sediment within and around a pockmark(s) would result in loss of the pockmark itself and its associated infaunal and epifaunal community. Small MDAC boulders are also likely to be removed. Therefore, resistance is assessed as **'None'**. In sedimentary habitats, pockmarks are like to reform and the community recolonize quickly once the sediment returns, which will depend on the nature of the sediment and the hydrographic regime. Therefore, resilience is assessed as **'Medium'** (2-10 years). Hence, sensitivity is assessed as **'Medium'**.

This pressure is considered 'Not relevant' on hard substrata. However, MDAC is considered a 'soft rock' (Whomersley *et al*., 2010) as it is easily bored by sponges and piddocks. Therefore, it may be possible for large sections of a reef of MDAC to be removed by extraction, together with its resident epifaunal and interstitial community. Therefore, resistance is assessed as **'None'** within the affected area. However, as MDAC forms very slowly (over 100s or 1000s of years; Bowden *et al*., 2013), resilience is assessed as **'Very low'** and sensitivity as **'High'**.

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

Dando (2001) suggested that the bottom of pockmarks may be less likely to be damaged by trawling, depending on their size, shape and depth. Webb *et al.* (2009b) examined the epifaunal community on MDAC within a complex of pockmarks between 160-235 m diameter and around 10 m deep, in the Norwegian Chanel, North Sea. They suggested that the depth of the pockmark protected the epifaunal community (on MDAC) within the pockmark from the effects of trawling. This was because trawl tracks were visible across the top of and near the pockmarks, fishing data indicated that the area was subject to a high intensity of fishing, and yet the diverse epifauna boasted large, long-lived, slow-growing gorgonian corals (*Paragongia arborea*) (Webb *et al*., 2009b).

In deep-water (>200 m) cold-seep communities of the New Zealand Hikurangi Margin, the seep megafauna (mussels, clams and tubeworms) were restricted to depressions and crevices in carbonates at several sites (Baco *et al*., 2010). Coral or vesicomyid shell debris, lost trawl gear, or trawl marks in adjacent sediments, accompanied these observations. Baco *et al.* (2010) suggested that trawling had disturbed the seep communities at most of the seep locations examined. In subsequent studies, increased trawling density was associated with reduced occurrence of live chemosynthetic fauna at sites in the Rock Garden region of the Hikurangi Margin. In addition, shallower sites had fewer live fauna and greater fishing intensity (Bowden *et al*., 2013).

Physical disturbance by fishing gear has been shown to adversely affect emergent epifaunal communities with hydroid and bryozoan matrices reported to be greatly reduced in fished areas (Jennings & Kaiser, 1998). For example, drop down video surveys of Scottish reefs exposed to trawling showed that visual evidence of damage to bryozoans and hydroids on rock surfaces was generally limited and restricted to scrape scars on boulders (Boulcott & Howell, 2011). The study showed that damage was incremental with damage increasing with the frequency of trawls rather than a blanket effect occurring on the pass of the first trawls. The level of impact may be mediated by the rugosity of the attachment, surfaces with greater damage occurring over smooth terrains where the fishing gear can move unimpeded across a flat surface. Therefore, MDAC reef communities may provide refuges for some species within burrows, under overhangs, or in crevices. Veale *et al.* (2000) reported that the abundance, biomass, and production of epifaunal assemblages decreased with increasing fishing effort. Re-sampling of grounds that were historically studied (from the 1930s) indicates that some upright species have increased in areas subject to scallop fishing (Bradshaw *et al.* 2002). This study also found increases in the tough stemmed hydroids including *Nemertesia* spp., whose morphology may prevent excessive damage. Bradshaw *et al.* (2002) suggested that as well as having high resistance to abrasion pressures, *Nemertesia* spp. have benthic larvae that could rapidly colonize disturbed areas with newly exposed substrata close to the adult. Similarly, increases in the abundance of the soft coral *Alcyonium digitatum* were found, although its increase was probably due to its ability to recover from fragments.

Re-sampling of grounds that were historically studied (from the 1930s) indicates that *Ophiothrix fragilis* has declined in areas subject to scallop fishing (Bradshaw *et al.*, 2002). Examination of historical and recent samples suggest that the spatial presence of *Ophiothrix fragilis* and *Amphiura* spp. in the North Sea has more than halved in comparison with the number of ICES rectangles in which they were sampled at the beginning of the century, apparently in response to fishing effort (Callaway *et al.*, 2007).

Rock burrowing fauna may receive protection by nature of their habit. For example, *Hiatella arctica* burrow depths were approximately 2 cm (mean length of *Hiatella arctica* individuals was 1-1.2 cm) with a maximum depth of 4 cm on limestone shores off the coast of Ireland (Trudgill & Crabtree, 1987). Clearly, the surface epifauna and flora are more susceptible to damage and removal by surface abrasion. However, burrows may weaken the MDAC and make it susceptible to damage by abrading activities, especially mechanical gear. Seffel (2010) reported that fishing gear "like bottom trawling nets are known to tear pieces off the carbonate structures", although no direct evidence was provided.

Sensitivity assessment. Shallow pockmarks may be disturbed by physical abrasion while deep pockmarks may provide protection to infauna and epifaunal at the bottom of the pockmark. Resistance is probably related to the depth and size of the pockmarks in the affected area. Therefore, resistance is probably **'Low'** except for deep pockmarks where the infauna and epifauna within the pockmark are protected from bottom gear. MDAC boulders and reefs are probably more susceptible to physical abrasion, especially from mechanical gear that may also damage the carbonate matrix itself. Therefore, resistance is also probably **'Low'**. Hence, resistance is assessed as **'Medium'** and sensitivity as **'Medium'** but with 'Low' confidence.

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

Dando (2001) suggested that the bottom of pockmarks may be less likely to be damaged by trawling, depending on their size, shape and depth. Webb *et al.* (2009b) examined the epifaunal community on MDAC within a complex of pockmarks between 160-235 m diameter and around 10 m deep, in the Norwegian Chanel, North Sea. They suggested that the depth of the pockmark protected the epifaunal community (on MDAC) within the pockmark from the effects of trawling. This was because trawl tracks were visible across the top of and near the pockmarks, fishing data indicated that the area was subject to a high intensity of fishing, and yet the diverse epifauna boasted large, long-lived, slow-growing gorgonian corals (*Paragongia arborea*) (Webb *et al.*, 2009b).

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Sensitivity assessment. Shallow pockmarks may be disturbed by physical disturbance while deep pockmarks may provide protection to infauna and epifaunal at the bottom of the pockmark. Resistance is probably related to the depth and size of the pockmarks in the affected area. It is assumed that penetrative gear would have a greater impact in soft sediments and on soft rocks but in the absence of any direct evidence, it is assumed to have at least the same potential impact as surface abrasion. Therefore, resistance is probably **'Low'** except for deep pockmarks where the infauna and epifauna within the pockmark are protected from bottom gear. MDAC boulders and reefs are probably more susceptible to physical disturbance, especially from mechanical gear that may also damage the carbonate matrix itself. Therefore, resistance is also probably **'Low'**. Hence, resistance is assessed as **'Medium'** and sensitivity as **'Medium'** but with 'Low' confidence.

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

Pockmarks occur in silty soft sediments and, therefore, depositional habitats. The rate of sedimentation and suspended sediment concentrations probably vary seasonally, and are probably higher in stormy winter months than relatively calm summer months. Gas seepage winnows away fines and creates the pockmark. The rate of seepage or periods of episodic seepage probably compensates for sedimentation. Dando (2001) noted that the rate of gas seepage was higher in shallow-water (<200 m) than deep-water (>200 m) because of the increased temperature and lower water pressure. Inactive pockmarks can act as sediment traps (and larval traps) (Dando, 2001). Croker *et al.* (2005) suggested that pockmarks could become covered with sediment in the event of high sedimentation rates and that buried pockmarks were not uncommon. However, visibility in deep pockmarks is often reduced due to high concentrations of suspended particulates that attract swarms of shrimps and euphausids (Dando, 2001). Therefore, an increase in suspended sediment (e.g. from intermediate to medium or high turbidity) may result in sedimentation and possibly the loss of inactive pockmarks. A similar increase may also infill activate pockmarks, although they will recover rapidly depending on the rates (and periodicity) of gas seepage. Hence, resistance is assessed as '**Medium**' and resilience is probably **'High'** for active seeps.

Where MDAC outcrops and boulder hosts epifaunal communities in pockmarks, then suspension feeders may be adversely affected by increases in suspended sediment. The presence of hard rock epifauna, as well as sediment epifauna (e.g. sea pens), suggests that pockmarks and their surrounds are rich feeding areas, an increase in suspended sediment may result in loss of some species depending on their individual tolerance to suspended sediments.

In most pockmarks and areas of carbonate reef, images show that the carbonate is surrounded by sediment, and is often partially covered by sediment. For example, In the Irish Sea, the MDAC reefs in Texel 11 occur in areas of strong tidal currents and mobile sands (Judd *et al*., 2007; Whomersely *et al*., 2010). The resident epifaunal community is typical of sand scoured rocky habitats, dominated by *Flustra foliacea* with abundant *Sabellaria spinulosa* (Whomersely *et al*., 2007). *Flustra foliacea* is probably tolerant of suspended sediment based on its occurrence in areas of high suspended sediment e.g. the turbid, fast flowing waters of the Menai Straits (Moore, 1977) and on tide-swept seabed, exposed to high levels of suspended sediment and sediment scour in the English Channel subject to sediment transport (mainly sand) and periodic, temporary, submergence by thin layers of sand (ca <5 cm) (Holme & Wilson 1985). The tide swept seabed communities in the English Channel were also characterized by the presence of *Urticina* spp. (Holme & Wilson, 1985). *Sabellaria spinulosa* is also associated with areas of high suspended sediment (Davies, *et al*., 2009; Last *et al*., 2011). Similarly, MDAC at the Croker Fault Zone was dominated by sparse *Nemertesia* sp. and *Sabellaria spinulosa* (O'Reilly *et al*., 2014). *Alcyonium digitatum* has been shown to be tolerant of high levels of suspended sediment. Hill *et al.* (1997) demonstrated that *Alcyonium digitatum* sloughed off settled particles with a large amount of mucous. *Alcyonium digitatum* is also known to inhabit the entrances to sea lochs (Budd, 2008) or the entrances to estuaries (Braber & Borghouts, 1977) where water clarity is likely to be highly variable.

Many encrusting sponges appear to be able to survive in highly sedimented conditions, and many species prefer such habitats (Bell & Barnes 2001; Bell & Smith 2004). Storr (1976) observed the sponge *Sphecispongia vesparium* backwashing to eject sediment and noted that other sponges (such as Condrilla nucula) use secretions to remove settled material. *Raspailia ramosa* and *Stelligera stuposa* have a reduced maximum size in areas of high sedimentation (Bell et al., 2002). Tjensvoll *et al.* (2013) found that *Geodia barretti* physiologically shuts down when exposed to sediment concentrations of 100 mg /l (86% reduction). Rapid recovery to initial respiration levels directly after the exposure indicated that *Geodia barretti* can cope with a single short exposure to elevated sediment concentrations. Schönberg (2015) reviewed and observed the interactions between sediments and marine sponges and described the lack of research on Porifera, with most studies grouping them together when looking at sediment effects. Her findings were that whilst many sponges are disadvantaged by sedimentation, many examples exist of sponges adapting to sediment presence, including through sediment incorporation, sediment encrusting, soft sediment anchoring using spicules and living, at least partially, embedded within the sediment. Schönberg (2015) found that *Polymastiida* interacted with sediment in 18.9% of observations (primarily through spicules), *Clionaida* had a highly variable interaction with sediment, with 5.7±11.4 %, *Tethyida* interacted in 13.1±21.1%. De Kluijver & Leewis (1994) monitored the marine species before and two years after construction of a storm barrier in the Oosterschelde Estuary. The barrier resulted in lower tidal flow, higher sedimentation and increased *Haliclona oculata* abundance.

Increased siltation can cause clogging of ascidians respiratory organs (Bakus, 1968). *Clavelina lepadiformis* has relatively wide apertures that help prevent clogging from particles (Naranjo *et al.*, 1996). The simplistic structure of its branchial sac (Fiala-Medioni, 1978) may be less efficient in expelling particles, and more likely to suffer from clogging of feeding apparatus than other forms of sea squirts, such as *Ciona intestinalis*. *Clavelina lepadiformis* was found to dominate Spanish harbours and nearby zones with a low rate of water renewal, excess silting and suspended matter and the species was described as biofouling and opportunist (Naranjo *et al.*, 1996).

Sensitivity assessment. The effect of increased suspended sediment will depend on the epifaunal community present. As shown above, many epifauna (Hydrozoa, Anthozoa, Bryozoa, Ascidiacea, and Porifera) are tolerant of high levels of suspended sediment and scour. In areas subject to high sediment load or scour, resistance is probably **'High'**. However, in areas of particular species richness (e.g. the Bubbling reefs of the Kattegat, Jensen *et al.*, 1992) an increase in suspended sediment may result in loss of some members of the epifaunal community, especially in areas of strong water movement and/or low suspended sediment loads. Therefore, a resistance of **'Medium'** is suggested. Resilience is probably **'High'**. Overall, sensitivity is assessed as **'Low'** but with 'Low confidence.

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

This pressure represents a single deposit of fine sediment to a depth of 5 cm. Pockmarks occur in silty soft sediments and, therefore, depositional habitats. The rate of sedimentation and suspended sediment concentrations probably vary seasonally, and are probably higher in stormy winter months than relatively calm summer months. Gas seepage winnows away fines and creates the pockmark. The rate of seepage or the periods of episodic seepage probably compensates for sedimentation. Dando (2001) noted that the rate of gas seepage was higher in shallow-water (<200 m) than deep-water (>200 m) because of the increased temperature and lower water pressure. Inactive pockmarks can act as sediment traps (and larval traps) (Dando, 2001). Croker *et al.* (2005) suggested that pockmarks could become covered with sediment in the event of high sedimentation rates and that buried pockmarks were not uncommon.

The effect of the deposit of 5 cm of fine sediment in a pockmark will depend on its size and depth. In the North Sea they are typically 50-100 m in diameter and 1-3 m deep, but small unitary pockmarks are very small (< 5m) while giant pockmarks may be 500 m across and >20 m deep and small funnels or small eye pockmarks are 3-5 m across and 0.5 m deep (Hovland & Judd, 1988; Judd & Hovland, 2007, Webb *et al.*, 2009). Therefore, a deposit of 5cm of fine sediment is unlikely to have an adverse effect, especially in active seeps. Hence, resistance and resilience are assessed a '**High'**, and the pockmark habitat is considered to be '**Not sensitive'** at the benchmark level.

In most pockmarks and areas of carbonate reef, images show that the carbonate is surrounded by sediment, and is often partially covered by sediment (Judd, 2005; Judd *et al.*, 2007; Whomersley *et al.*, 2010; O'Reilly *et al.*, 2014). For example, In the Irish Sea, the MDAC reefs in Texel 11 occur in areas of strong tidal currents and mobile sands (Judd *et al.*, 2007; Whomersley *et al.*, 2010) and the carbonate reefs were usually only 40% uncovered. Whomersley *et al.* (2010) described three epifaunal communities depending on their height above the sediment. MDAC at least 20 cm above the sediment included a diverse community of epifauna, while MDAC lower than 20 cm was characterized by scour resistant epifauna (e.g. *Flustra foliacea*) and low relief MDAC was un-colonized by epifauna. It is probable that the reef undergoes regular periods of smothering and uncovering due to movement of sediment. Dando *et al.* (1994) noted that the intertidal and shallow subtidal MDAC reef the Kattegat was exposed, colonized by barnacles, mytilids etc. and eroded before being buried again. In the Codling Fault Zone, the MDAC forms mounds ca 5-10 m above the seabed and in Holden Reefs, the MDAC stands up to 1.5 m above the seabed (Judd *et al.*, 2007).

Overall, the effect of a deposit of 5 cm on MDAC reefs depends on their size and height above the seabed. In pockmarks, small boulders may be affected slightly, and even on large areas of MDAC (e.g. the carbonate reefs of Texel and Holden Reefs) may be covered on the surface. However, many of the species present are probably adapted to sedimentation (see suspended sediment above). In addition, the action of gas seepage or strong water movement will probably remove the deposit rapidly. Hence, resistance and resilience are assessed a '**High'**, and the habitat is considered to be '**Not sensitive'** at the benchmark level but with 'Low confidence.

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

This pressure represents a single deposit of fine sediment to a depth of 30 cm. Pockmarks occur in silty soft sediments and, therefore, depositional habitats. The rate of sedimentation and suspended sediment concentrations probably vary seasonally, and are probably higher in stormy winter months than relatively calm summer months. Gas seepage winnows away fines and creates the pockmark. The rate of seepage or the periods of episodic seepage probably compensates for sedimentation. Dando (2001) noted that the rate of gas seepage was higher in shallow-water (<200 m) than deep-water (>200 m) because of the increased temperature and lower water pressure. Inactive pockmarks can act as sediment traps (and larval traps) (Dando, 2001). Croker *et al.* (2005) suggested that pockmarks could become covered with sediment in the event of high sedimentation rates and that buried pockmarks were not uncommon.

The effect of the deposit of 30 cm of fine sediment in a pockmark will depend on its size and depth. In the North Sea they are typically 50-100 m in diameter and 1-3 m deep, but small unitary pockmarks are very small (< 5m) while giant pockmarks may be 500 m across and >20 m deep and small funnels or small eye pockmarks are 3-5 m across and 0.5 m deep (Hovland & Judd, 1988; Judd & Hovland, 2007, Webb *et al.*, 2009). Therefore, while large and deep pockmarks are probably not affected, a deposit of 30 cm of fine sediment may affect small pockmarks and result in a short-term alteration in the infaunal community. However, where the pockmarks are active, the deposited material may be removed rapidly. Hence, the resistance of pockmarks is assessed as **‘Medium’**, resilience as **‘High’** and the sensitivity is assessed as **‘Low’** at the benchmark level.

In most pockmarks and areas of carbonate reef, images show that the carbonate is surrounded by sediment, and is often partially covered by sediment (Judd, 2005; Judd *et al.*, 2007; Whomersley *et al.*, 2010; O’Reilly *et al.*, 2014). For example, In the Irish Sea, the MDAC reefs in Texel 11 occur in areas of strong tidal currents and mobile sands (Judd *et al.*, 2007; Whomersley *et al.*, 2010) and the carbonate reefs were usually only 40% uncovered. Whomersley *et al.* (2010) described three epifaunal communities depending on their height above the sediment. MDAC at least 20 cm above the sediment included a diverse community of epifauna, while MDAC lower than 20 cm was characterized by scour resistant epifauna (e.g. *Flustra foliacea*) and low relief MDAC was un-colonized by epifauna. It is probable that the reef undergoes regular periods of smothering and uncovering due to movement of sediment. Dando *et al.* (1994) noted that the intertidal and shallow subtidal MDAC reef the Kattegat was exposed, colonized by barnacles, mytilids etc. and eroded before being buried again. In the Codling Fault Zone, the MDAC forms mounds ca 5-10 m above the seabed and in Holden Reefs, MDAC stands up to 1.5 m above the seabed (Judd *et al.*, 2007).

Overall, the effect of a deposit of 30 cm on MDAC reefs depends on their size and height above the seabed. In pockmarks, small boulders may be buried and the epifauna adversely affected, depending on the time taken for the deposit to be removed by active gas seepage or water flow. Large areas of MDAC (e.g. the carbonate refs of Texel and Holden Reefs) may be covered on the surface. In the Texel 11 reefs (Whomersley *et al.*, 2010) a difference in height above the sediment of ca 20 cm made a significant difference to the epifaunal community. Therefore, a deposit of 30 cm may adversely affect the epifaunal community. Nevertheless, in areas of strong currents (e.g. Texel 11) the deposited sediment may not remain for more than one tidal cycle, and any effect would be minimal. In addition, many of the species present are probably adapted to sedimentation (see suspended sediment above).

Therefore, a deposit of 30 cm of fine sediment may adversely affect the epifaunal community and reduce species richness where the MDAC reef is adjacent to the sediment, and/or the MDAC is of low relief. Hence, the resistance of MDAC structures is assessed a **‘Medium’**, resilience as **‘High’** and the sensitivity is assessed as **‘Low’** at the benchmark level but with ‘Low confidence. However, in areas of strong water flow, the effect is probably minimal and the MDAC reef is probably ‘**Not sensitive’** at the benchmark level (resistance and resilience are assessed a ‘**High’**).

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

Litter is common on the seabed of the Greater North Sea, Celtic Seas and Eastern Bay of Biscay (OSPAR, 2017) and commonly reported in the deep sea (Ramirez-Llodra *et al.*, 2011). Litter includes hard plastics but also glass, clinker, barrels, and nets (Ramirez-Llodra *et al.*, 2011; OSPAR, 2017). Discarded or lost nets and lines may continue to 'ghost fish', while hard plastics, moved by currents may result in physical disturbance and abrasion, may provide additional hard substrata for colonization by epifauna, or may introduce non-native species or adsorb contaminants. Micro-plastics also adsorb contaminants and may be ingested by marine fauna (Wright *et al.*, 2013). However, information on the direct effects of litter on benthic fauna, especially micro-plastics, are limited. Hence, 'no assessment' of sensitivity has been recorded.

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

Underwater noise changes	High Q: Medium A: Low C: Low	High Q: High A: High C: High	Not sensitive Q: Medium A: Low C: Low

Stanley *et al.* (2014) studied the effects of vessel noise on fouling communities and found that the bryozoans *Bugula neritina*, *Watersipora arcuate* and *Watersipora subtorquata* responded positively. More than twice as many bryozoans settled and established on surfaces with vessel noise (128 dB in the 30–10,000 Hz range) compared to those in silent conditions. Growth was also significantly higher in bryozoans exposed to noise, with 20% higher growth rate in encrusting and 35% higher growth rate in branching species. However, the majority of epifaunal and infaunal species are unlikely to respond directly to underwater noise. Fish associated with MDAC reefs or pockmarks may exhibit avoidance responses to underwater noise but are considered to be vagrants that use the habitat for shelter, rather than characterizing species.

Sensitivity assessment. Resistance to this pressure is assessed as **'High'** and resilience as **'High'.** This biotope is therefore considered to be **'Not sensitive'** at the benchmark level.

Introduction of light or shading	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

The introduction of artificial light is unlikely to be relevant to seeps (pockmarks or reefs of MDAC) unless they occur in the shallow subtidal and even then the effects are probably limited to slight changes in the timing of reproduction due to changes in circadian rhythms, although there is no evidence to substantiate this idea. Shading is also only likely to affect the depth to which macroalgae penetrate the water column and it only likely to affect MDAC reefs that are shallow enough to support macroalgae, e.g. Holdens Reefs that support filamentous red and brown algae on the upper surfaces. Shading has the potential to reduce the limit of macroalgae and reduce their diversity but long-term or permanent artificial structures are unlikely to occur outside inshore waters. Therefore, this pressure is probably 'Not relevant' in this habitat.

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

Barriers and changes in tidal excursion are 'Not relevant' to biotopes restricted to open waters.

Death or injury by collision	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant to seabed habitats. NB. Collision by grounding vessels is addressed under ‘surface abrasion’.

Visual disturbance	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant

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

There is no evidence to suggest that the dominant species within the infauna of pockmarks or epifauna on MDAC (methane-derived authigenic carbonate) are subject to genetic modification of translocation.

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

Didemnum vexillum is an invasive colonial sea squirt native to Asia which was first recorded in the UK in Darthaven Marina, Dartmouth in 2005. *Didemnum vexillum* can form extensive mats over the substrata it colonizes, binding boulders, cobbles and altering the host habitat (Griffith *et al*., 2009). *Didemnum vexillum* can also grow over and smother the resident biological community. Recent surveys within Holyhead Marina, North Wales have found *Didemnum vexillum* growing on and smothering native tunicate communities, including *Ciona intestinalis* (Griffith *et al*., 2009). Due to the rapid-re-colonization of *Didemnum vexillum* eradication attempts have to date failed.

Didemnum vexillum is isolated to several sheltered locations in the UK (GBNNSIP, 2014; NBN, 2015), however, *Didemnum vexillum* successfully colonized offshore in Georges Bank, USA (Lengyel *et al*., 2009), which is more exposed than the locations that *Didemnum vexillum* has colonized in the UK. It is, therefore, possible that *Didemnum vexillum* could pose a threat to epifaunal communities on refs of MDAC (methane-derived authigenic carbonate).

A number of invasive bryozoans are of concern including *Schizoporella japonica* (Ryland *et al*., 2014) and *Tricellaria inopinata* (Dyrynda *et al*., 2000; Cook *et al*., 2013b). *Tricellaria inopinata* has been reported to colonize the byssal threads of the mussel *Mytilus galloprovincialis*, *Hymeniacidon perleve* and the ascidian *Styela plicata* (Dyrynda *et al*., 2000). *Tricellaria inopinata* dominated the fouling community in the Lagoon of Venice, within seven years of being introduced (Ambrogi, 2000).

The red king crab, *Paralithodes camtschaticus* was introduced into the East Barents Sea in the 1960s and has spread east along the Kola Peninsula and westwards into Norwegian waters (GBNNSIP, 2011). It is not recorded in UK waters at present. It is a voracious omnivore and scallop and flatfish populations have been reduced in Norway (GBNNSIP, 2011). If it reached UK waters, it has the potential to adversely affect epifaunal communities.

However, there is 'No evidence' at present that this habitat has been affected by introduced non-native invasive species. Due to the constant risk of new invasive species, the literature for this pressure should be revisited.

Introduction of microbial pathogens	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

Numerous species of epifauna harbour parasites (e.g. bryozoans) and all species are probably targeted by parasites and pathogens. However, no evidence of disease induced mortality in the species typical of pockmark or MDAC reef communities was found.

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

Several fish species that are found associated with pockmarks (e.g. cod, ling) are targeted by commercial fisheries. Similarly, the sediment in pockmarks may also harbour *Nephrops*. Judd & Hovland (2007) suggested that the majority of scavengers and predators were 'vagrants'. Mobile scavengers (e.g. starfish and crustaceans) probably utilise the available habitat. However, they would move to other habitats if the pockmark or MDAC was lost or covered. The fish most likely use pockmarks and MDAC structures for shelter and forage elsewhere, as fish are also attracted to artificial structures and even to depressions on the seabed (Dando, 2001, 2010). Therefore, loss of these species will probably not have a significant effect on the ecology of the pockmark infauna or the epifauna of MDAC in pockmarks or on reefs. Therefore, a resistance of **'High'** is suggested. Hence, resilience is also **'High'** and the habitat is assessed as **'Not sensitive'**. Please note, the physical effects of commercial harvesting (e.g. trawling) are addressed under the 'physical' pressures above (see abrasion').

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

Pockmarks may be affected by trawling or bottom gear depending on their size and depth. It is possible that shallow pockmarks could be disturbed by bottom gear and species removed from the pockmark or its slopes (see 'abrasion' above). However, removal of emergent infauna (e.g. sea pens or sea anemones) from the slopes of pockmarks or removal of a proportion of the macro-infauna as by-catch may not adversely affect the character of the pockmark community as the microbial and meiofaunal communities will probably remain. Therefore, resistance is probably **'Medium'** and resilience **'High'**, and sensitivity is assessed as **'Low'** but with 'Low' confidence. Note, the physical effects of commercial harvesting (e.g. trawling) are addressed under the 'physical' pressures above (see abrasion') and only the possible biological interactions are discussed here.

Epifaunal species present on boulders and outcrops of MDAC in pockmarks or on reefs probably compete for space and overgrow each other. Space cleared by a physical pressure is likely to be rapidly colonized by hydroids and tubeworms with subsequent succession from hydroids to erect bryozoan and anemones (see Sebens, 1985, 1986). By-catch (e.g. due to passing bottom gears) could potentially remove a proportion of the epifaunal community, and a resistance of **'Low'** is suggested. Therefore, resilience is probably **'Medium'** and a sensitivity is assessed a **'Medium'**.

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