



MarLIN

Marine Information Network

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

Bubbling reefs in the aphotic zone

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

Dr Harvey Tyler-Walters

2018-02-28

A report from:

The Marine Life Information Network, Marine Biological Association of the United Kingdom.

Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [<https://www.marlin.ac.uk/habitats/detail/1163>]. All terms and the MarESA methodology are outlined on the website (<https://www.marlin.ac.uk>)

This review can be cited as:

Tyler-Walters, H. 2018. Bubbling reefs in the aphotic zone. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom.
DOI <https://dx.doi.org/10.17031/marlinhab.1163.1>



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

(page left blank)



Researched by Dr Harvey Tyler-Walters

Refereed by Admin

Summary

☰ UK and Ireland classification

EUNIS 2008 A5.712 Bubbling reefs in the aphotic zone

JNCC 2015 A5.712

JNCC 2004

1997 Biotope

➔ Description

'Bubbling reefs' occur when slabs, pavements, cliffs and pillars of methane-derived authigenic carbonate (MDAC) deposits are exposed by removal of sediment. The MDAC deposits are created within the sediment by the microbial oxidation of methane from gas seeps. The carbonate can cement the sediment to form extensive layers or cliffs of hard substrata. In the Kattegat, Denmark, the MDAC forms slabs up to 10 m² 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 500,000 m² in Texel II and another 10,000 m² 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).

The MDAC provides hard substratum for colonization by a diverse community of filter feeding and passive predatory epifauna typical of the sublittoral hard substrata in the surrounding area. 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. Mats of sulphide-oxidizing bacteria *Beggiatoa*, *Thiothrix* and *Thioplaca*, may form in areas in direct contact with the gas, which may support its own community of grazing ciliates and nematodes and predatory nematodes.

However, the epifaunal community varies with location. For example in the Kattegat 'bubbling reefs', the most conspicuous anthozoans were *Metridium dianthus* (as senile), growing on the uppermost parts of pillar and slabs, with *Alcyonium digitatum* growing in patches in protected areas while *Urticina felina* occurred at the foot of the carbonate formations. *Mytilus edulis* colonized the upper parts of 'pillars' of MDAC. Burrows created by sponges and *Hiatella* sp. provide additional niches for colonization. Overhangs and caves near the sediment surface provided shelter for cod (*Gadus morhua*) and saithe (*Pollachius virens*). The MDAC also provided niches for crabs (e.g. *Cancer pagurus*) and lobster (e.g. *Homarus vulgaris*) (Jensen et al., 1992). Jensen et al. (1992) recorded a range of hydroids, anthozoans, nemeteans, polychaetes, gastropods, bivalves, barnacles, decapods, isopods, amphipods, bryozoans, ascidians and ophiuroids, using the MDAC for substratum or shelter. In other areas (inc. pockmarks) MDAC is typically bored by *Hiatella* and sponges (Jensen et al., 1992; Dando, 2001; Webb et al., 2009b; Whomersley et al., 2010b; O'Reilly et al., 2014). In the mid-Irish Sea, MDAC was subject to strong water flow and mobile sediment. Whomersley et al. (2010) described three epifaunal communities depending on their height above the sediment. MDAC at least 20 cm above the sediment was colonized by erect suspension-feeders inc. *Alyconium digitatum*, *Tubularia indivisa*, *Eucratea loricata*, *Flustra foliacea*, *Vesicularia spinosa*, and *Diphasis pinaster*, occassional sponges inc. *Cliona celata* and *Iophonopsis nigricans*, the anemones *Sagartia troglodytes* and *Cerianthus lloydii*, and tubeworms *Sabella pavonina* and *Sabellaria spinulosa*. MDAC lower than 20 cm was characterized by scour resistant epifauna e.g. *Flustra foliacea* and *Vesicularia spinosa* with short turf forming bryozoans and occasional hardy hydroids e.g. *Tubularia indivisa*, *Nemertesia* spp. and *Diphasia pinaster*. *Sabellaria spinulosa* was often found to be superabundant and cover the MDAC at this height. Very low relief MDAC was generally uncolonized by epifauna (Whomersley et al., 2010). However, the MDAC features in the Colding Fault Zone investigated by O'Reilly et al. (2014) were depauperate by comparison with Holdens Reefs, with a few specimens of *Nemertesia* spp. and tubes of *Sabellaria* spp. recorded. Description derived from (Dando & Hovland, 1992; Jensen et al., 1992; Dando, 2001; Judd & Hovland, 2007, Judd et al., 2007; Webb et al., 2009b; Dando, 2010; Whomersley et al., 2010b; O'Reilly et al., 2014).

↓ Depth range

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

☰ Additional information

✓ Listed By

- none -

Further information sources

Search on:

G g G JNCC

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

'Bubbling reefs' occur when slabs, pavements, cliffs and pillars of methane-derived authigenic carbonate (MDAC) deposits are exposed by removal of sediment. The MDAC deposits are created within the sediment by the microbial oxidation of methane from gas seeps. The carbonate can cement the sediment to form extensive layers or cliffs of hard substrata. 'Bubbling reefs' create 'oases' of diversity in otherwise sedimentary habitats (Jensen *et al.*, 1992; Hovland & Judd, 1988; Judd & Hovland, 2007; Webb *et al.*, 2009; Dando, 2010). 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).

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). However, 'bubbling reefs' also host methane-oxidizing bacteria and archaea, and bacterial mats. 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. However, epifauna are not excluded due to the rapid dissolution of seep gases in the water column (Dando, 2010).

Judd & Hovland (2007) suggested that majority of scavengers and predators in shallow-water (<200 m) cold seep habitats were 'vagrants'. Mobile scavengers (e.g. starfish and crustaceans) probably utilise the available habitat. However, they would move to other habitats if the MDAC was lost or covered. Similarly, fish most likely use 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).

'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. 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. However, they can host a diverse epifauna dependent on their surrounding area and depth. Therefore, sensitivity assessment for 'bubbling reefs' focuses on the physical habitat (the MDAC) 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.

Resilience and recovery rates of habitat

'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 epifaunal communities of shallow-water (<200 m) cold seeps or ‘bubbling’ reefs was found. Recolonization rates are probably similar to those for similar 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 on MDAC boulder, outcrop or reef 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 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 (Eggleson, 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.

Flustra foliacea colonies are perennial, and potentially highly fecund with increasing colony size (Eggleson, 1972b) with ca 10,000 larvae released from a specimen of *Flustra foliacea* within 3 hrs (Dalyell, cited in Hincks, 1880). Once settled, new colonies of *Flustra foliacea* take at least 1 year to develop erect growth and 1-2 years to reach maturity, depending on environmental conditions (Tillin & Tyler Walters, 2014). Four years after sinking off Lundy, the M.V. Roberts was found to be colonized by erect bryozoans and hydroids, including occasional *Flustra foliacea*. Whilst bryozoan larvae are typically very short-lived, limiting recruitment to the immediate area surrounding breeding colonies, specimens experiencing strong water movement would improve dispersal potential and may explain reports of *Flustra foliacea* colonizing the MV Roberts (Hiscock, 1981; Tyler-Walters & Ballerstedt, 2007). Fariñas-Franco et al. (2014) recorded the colonization of an artificial reef constructed of 16 tonnes of king scallop shells (*Pecten maximus*) deployed in Strangford Loch in February 2010. The reef was then seeded with translocated *Modiolus modiolus* in March 2010. Among other species, *Flustra foliacea* had colonized the reef within 6 months of the reef construction. *Flustra foliacea* was also recorded locally prior to construction of the reef, and therefore recruitment may have a local source.

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 by 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 enters 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 steadily 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**' but where resistance is 'Low' or 'None' and the epifaunal community is significantly affected by a pressure, then resilience is probably **Medium** (2-10 years). However, examples of MDAC subject to periodic burial or scour are probably dominated by rapid colonizing species at low abundance so that recovery of the depauperate fauna may be rapid and resilience is likely to be '**High**'.

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 lamellibrachia 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. Whomersley *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. 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

Epifaunal communities on boulders and outcrops of MDAC (methane-derived authigenic carbonate) and extensive areas of MDAC in 'bubbling reefs' are opportunistic species drawn from the surrounding area. Therefore, the exact epifaunal communities present on MDAC (e.g. the Irish Sea) may vary with 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.

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
---	-----------------------------------	--	--

Epifaunal communities on boulders and outcrops of MDAC (methane-derived authigenic carbonate) and extensive areas of MDAC in 'bubbling reefs' are opportunistic species drawn from the surrounding area. Therefore, the exact epifaunal communities present on MDAC (e.g. from the Irish Sea) may vary with 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

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). The resident infauna and epifauna is likely to be adapted to the salinity regime in which the 'bubbling 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. Russo *et al.* (2007) reported changes in the community structure of soft sediment communities due to desalination 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). The resident infauna and epifauna is likely to be adapted to the salinity regime in which the 'bubbling 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)	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low
---	-----------------------------------	--	--

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.

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 (A5.712).

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
--------------------------------------	-----------------------------------	--	--

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

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 than 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 in the vicinity of gas outlets are adapted to low oxygen conditions and are unlikely to be adversely affected by a reduction in oxygen levels at the benchmark levels. 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. 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. Active 'bubbling reefs' are likely to exhibit nutrient enrichment in the vicinity of the gas outlets. Therefore, the effect of additional nutrient enrichment will probably depend on the degree of gas seepage and distance from the gas outlet(s). Extensive reefs that host a diverse epifaunal community may see 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. POC inputs can come from chemosynthetic bacteria, heterotrophic prokaryotes, cyanobacteria, benthic diatoms, photosynthetic plankton and marine and terrestrial plants (Dando, 2010).

Bacterial mats of sulphur bacteria (*Beggiatoa*, *Thiothrix* and *Thioploca* 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 *Haliclona 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. Epifaunal communities 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'.

A Physical Pressures

	Resistance	Resilience	Sensitivity
Physical loss (to land or freshwater habitat)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

All marine habitats and benthic species are considered to have a resistance of 'None' to this pressure and to be unable to recover from a permanent loss of habitat (resilience is 'Very Low'). Sensitivity within the direct spatial footprint of this pressure is, therefore, 'High'. Although no specific evidence is described confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

	Resistance	Resilience	Sensitivity
Physical change (to another seabed type)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

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 take 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**'.

Physical change (to another sediment type)	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
---	---	---	---

MDAC forms within the sediment and is exposed in pockmarks or as extensive reefs. Whomersley *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 reefs 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.

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
---	-----------------------------------	--	-------------------------------------

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: Medium A: Low C: Low	Medium Q: Medium A: Low C: Low	Medium Q: Medium A: Low C: Low
--	---------------------------------------	--	--

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. MDAC boulders and reefs are probably susceptible to physical abrasion, especially from mechanical gear that may also damage the carbonate matrix itself. Therefore, resistance is probably '**Low**'. Hence, resistance is assessed as '**Medium**' and sensitivity as '**Medium**' but with '**Low**' confidence.

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

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 hydrozoan 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. MDAC boulders and reefs are probably 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	High	Low
	Q: Low A: NR C: NR	Q: Medium A: Low C: Low	Q: Low A: Low C: Low

In most 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; Whomersley *et al.*, 2010). The resident epifaunal community is typical of sand scoured rocky habitats, dominated by *Flustra foliacea* with abundant *Sabellaria spinulosa* (Whomersley *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 *Condrlilla 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 $5.7 \pm 11.4\%$, *Tethyida* interacted in $13.1 \pm 21.1\%$. 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. In most 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. 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. In most 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).

The effect of a deposit of 30 cm on MDAC reefs depends on their size and height above the seabed. Large areas of MDAC (e.g. the carbonate reefs 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
<p>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 <i>et al.</i>, 2011). Litter includes hard plastics but also glass, clinker, barrels, and nets (Ramirez-Llodra <i>et al.</i>, 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 <i>et al.</i>, 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.</p>			

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
<p>No evidence</p>			
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
<p>The introduction of artificial light is unlikely to be relevant to seeps (pockmarks or reefs of MDAC)</p>			

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. Holden's 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. However, this habitat (A5.712) is defined as aphotic. Therefore, this pressure is '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 epifauna on MDAC (methane-derived authigenic carbonate) are subject to genetic modification or 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)	Not relevant (NR)	No evidence (NEv)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	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 MDAC reef communities was found.

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

Several fish species that are found associated with methane-derived authigenic carbonate (MDAC) reef (e.g. cod, saithe) are targeted by commercial fisheries. 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 MDAC reef was lost or covered. The fish most likely use 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 epifauna of MDAC 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	Medium	Medium
	Q: Low A: NR C: NR	Q: Medium A: Low C: Low	Q: Low A: Low C: Low

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**'. 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.

Bibliography

- Allen, J., Slinn, D., Shummon, T., Hurtnoll, R. & Hawkins, S., 1998. Evidence for eutrophication of the Irish Sea over four decades. *Limnology and Oceanography*, **43** (8), 1970-1974.
- Ambrogi, A.O., 2000. Biotic invasions in a Mediterranean lagoon. *Biological Invasions*, **2** (2), 165-176.
- Baco, A.R., Rowden, A.A., Levin, L.A., Smith, C.R. & Bowden, D.A., 2010. Initial characterization of cold seep faunal communities on the New Zealand Hikurangi margin. *Marine Geology*, **272** (1), 251-259. DOI <https://doi.org/10.1016/j.margeo.2009.06.015>
- Bakus, G.J., 1968. Sedimentation and benthic invertebrates of Fanning Island, Central Pacific. *Marine Geology*, **6**, 45-51.
- Bell, J.J. & Barnes, D.K., 2001. Sponge morphological diversity: a qualitative predictor of species diversity? *Aquatic Conservation: Marine and Freshwater Ecosystems*, **11** (2), 109-121.
- Bell, J.J. & Smith, D., 2004. Ecology of sponge assemblages (Porifera) in the Wakatobi region, south-east Sulawesi, Indonesia: richness and abundance. *Journal of the Marine Biological Association of the UK*, **84** (3), 581-591.
- Bell, J.J., Barnes, D. & Shaw, C., 2002. Branching dynamics of two species of arborescent demosponge: the effect of flow regime and bathymetry. *Journal of the Marine Biological Association of the UK*, **82** (2), 279-294.
- Bishop, G.M. & Earll, R., 1984. Studies on the populations of *Echinus esculentus* at the St Abbs and Skomer voluntary Marine Nature Reserves. *Progress in Underwater Science*, **9**, 53-66.
- Bolam, S.G. & Fernandes, T.F., 2002. Dense aggregations of tube-building polychaetes: response to small-scale disturbances. *Journal of Experimental Marine Biology and Ecology*, **269**, 197-222.
- Boulcott, P. & Howell, T.R.W., 2011. The impact of scallop dredging on rocky-reef substrata. *Fisheries Research* (Amsterdam), **110** (3), 415-420.
- Bowden, D.A., Rowden, A.A., Thurber, A.R., Baco, A.R., Levin, L.A. & Smith, C.R., 2013. Cold Seep Epifaunal Communities on the Hikurangi Margin, New Zealand: Composition, Succession, and Vulnerability to Human Activities. *PLoS ONE*, **8** (10), e76869.
- Braber, L. & Borghouts, C.H., 1977. Distribution and ecology of Anthozoa in the estuarine region of the rivers Rhine, Meuse and Scheldt. *Hydrobiologia*, **52**, 15-21.
- Bradshaw, C., Veale, L.O., Hill, A.S. & Brand, A.R., 2002. The role of scallop-dredge disturbance in long-term changes in Irish Sea benthic communities: a re-analysis of an historical dataset. *Journal of Sea Research*, **47**, 161-184.
- Brault, S. & Bourget, E., 1985. Structural changes in an estuarine subtidal epibenthic community: biotic and physical causes. *Marine Ecology Progress Series*, **21**, 63-73.
- Buchanan, J.B. & Warwick, R.M., 1974. An estimate of benthic macrofaunal production in the offshore mud of the Northumberland coast. *Journal of the Marine Biological Association of the United Kingdom*, **54**, 197-222.
- Castric-Fey, A., 1974. *Les peuplements sessiles du benthos rocheux de l'archipel de Glénan (Sud-Bretagne). Ecologie descriptive et expérimentale.* , Ph. D. thesis, Université de Bretagne Occidentale, L' Université Paris, Paris, France.
- Cazeau, C., 1970. *Recherches sur l'écologie et le développement larvaire des Polychètes d'Arcachon.* , These de Doctorat es Sciences, Bordeaux, 295, 1-395.
- Cornelius, P.F.S., 1992. Medusa loss in leptolid Hydrozoa (Cnidaria), hydroid rafting, and abbreviated life-cycles among their remote island faunae: an interim review.
- Cornelius, P.F.S., 1995b. *North-west European thecate hydroids and their medusae. Part 2. Sertulariidae to Campanulariidae.* Shrewsbury: Field Studies Council. [Synopses of the British Fauna no. 50]
- Croker, P.F., Kozachenko, M. & Wheeler, A.J., 2005. Gas-related seabed structures in the western Irish Sea (IRL-SE6). UK Department of Trade and Industry's offshore energy Strategic Environmental Assessment Programme, London, 120 pp.
- Dando, P.R., 2010. Biological communities at marine shallow-water vent and seep sites. In Keil, S. (ed.) *The Vent and Seep Biota: Aspects from Microbes to Ecosystems*. Topics in Geobiology 33. Dordrecht: Springer Science & Business Media, pp. 333-378.
- Dando, P.R. & Hovland, M., 1992. Environmental effects of submarine seeping natural gas. *Continental Shelf Research*, **12** (10), 1197-1207. DOI [https://doi.org/10.1016/0278-4343\(92\)90079-Y](https://doi.org/10.1016/0278-4343(92)90079-Y)
- Dando, P.R. & Southward, A.J., 1986. Chemoautotrophy in bivalve molluscs of the Genus *Thyasira*. *Journal of the Marine Biological Association of the United Kingdom*, **60**, 915-929.
- Dando, P.R. & Spiro, B., 1993. Varying nutritional dependence of the thyasirid bivalves *Thyasira sarsi* and *Thyasira equalis* on chemoautotrophic symbiotic bacteria, demonstrated by isotope ratios of tissue carbon and shell carbonate. *Marine Ecology Progress Series*, **92**, 151-158.
- Dando, P.R., 2001. A review of pockmarks in the UK part of the North Sea, with particular respect to their biology. *Technical report produced for Strategic Environmental Assessment - SEA2*. UK: Department of Trade and Industry, pp. 21
- Dando, P.R., Austen, M.C., Burke, R.A., Kendall, M.A., Kennicutt, M.C., Judd, A.G., Moore, D.C., O'Hara, S.C.M., Schmaljohann, R. & Southward, A.J., 1991. Ecology of a North Sea pockmark with an active methane seep. *Marine Ecology Progress Series*, **70** (1), 49-63.
- Dando, P.R., Jensen, P., O'Hara, S.C.M., Niven, S.J., Schmaljohann, R., Schuster, U. & Taylor, L.J., 1994. The effects of methane seepage at an intertidal/shallow subtidal site on the shore of the Kattegat, Vendsyssel, Denmark. *Bulletin of the Geological Society of Denmark*, **41**, 65-79.

- Davies, A.J., Duineveld, G.C., Lavaleye, M.S., Bergman, M.J., van Haren, H. & Roberts, J.M., 2009. Downwelling and deep-water bottom currents as food supply mechanisms to the cold-water coral *Lophelia pertusa* (Scleractinia) at the Mingulay Reef complex. *Limnology and Oceanography*, **54** (2), 620.
- De Kluijver, M. & Leewis, R., 1994. Changes in the sublittoral hard substrate communities in the Oosterschelde estuary (SW Netherlands), caused by changes in the environmental parameters. *Hydrobiologia*, **282** (1), 265-280.
- Dyrynda, P., Fairall, V., Occhipinti Ambrogi, A. & d'Hondt, J.-L., 2000. The distribution, origins and taxonomy of *Tricellaria inopinata* d'Hondt and Occhipinti Ambrogi, 1985, an invasive bryozoan new to the Atlantic. *Journal of Natural History*, **34** (10), 1993-2006.
- Dyrynda, P.E.J., 1994. Hydrodynamic gradients and bryozoan distributions within an estuarine basin (Poole Harbour, UK). In *Proceedings of the 9th International Bryozoaology conference, Swansea, 1992. Biology and Palaeobiology of Bryozoans* (ed. P.J. Hayward, J.S. Ryland & P.D. Taylor), pp.57-63. Fredensborg: Olsen & Olsen.
- Edwards, C.B. & Moore, C.G., 2008. Reproduction in the sea pen *Pennatula phosphorea* (Anthozoa: Pennatulacea) from the west coast of Scotland *Marine Biology* **155**:303-314
- Edwards, D.C.B. & Moore, C.G., 2009. Reproduction in the sea pen *Funiculina quadrangularis* (Anthozoa: Pennatulacea) from the west coast of Scotland. *Estuarine, Coastal and Shelf Science*, **82**, 161-168.
- Eggleston, D., 1972b. Factors influencing the distribution of sub-littoral ectoprocts off the south of the Isle of Man (Irish Sea). *Journal of Natural History*, **6**, 247-260.
- Fauvel, P., 1927. Polychètes sédentaires. In *Faune de France*, **16**, 494 pp. Paris: P. Lechevalier.
- Ferns, P.N., Rostron, D.M. & Siman, H.Y., 2000. Effects of mechanical cockle harvesting on intertidal communities. *Journal of Applied Ecology*, **37**, 464-474.
- Fiana-Medioni, A., 1978. A scanning electron microscope study of the branchial sac of benthic filter-feeding invertebrates (ascidians). *Acta Zoologica*, **59**, **1**, 1-9.
- Fish, J.D. & Fish, S., 1996. *A student's guide to the seashore*. Cambridge: Cambridge University Press.
- GBNNSIP, 2011. Red King Crab, *Paralithodes camtschaticus*. Factsheet. [online]. York, GB Nonnative Species Secretariat. Available from: <http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=2533> [Accessed 05/05/2016]
- GBNNSIP 2018. Carpet sea squirt *Didemnum vexillum*. Factsheet. [online]. York, GB Nonnative Species Secretariat. Available from: <http://www.nonnativespecies.org/factsheet/factsheet.cfm?speciesId=1209> [Accessed: 04/03/2016]
- Gili, J.-M. & Hughes, R.G., 1995. The ecology of marine benthic hydroids. *Oceanography and Marine Biology: an Annual Review*, **33**, 351-426.
- Grassle, J.F. & Grassle, J.P., 1974. Opportunistic life histories and genetic systems in marine benthic polychaetes. *Journal of Marine Research*, **32**, 253-284.
- Gray, J.S., 1979. Pollution-induced changes in populations. *Philosophical Transactions of the Royal Society of London, Series B*, **286**, 545-561.
- Gray, J.S., Wu R.S.-S. & Or Y.Y., 2002. Effects of hypoxia and organic enrichment on the coastal marine environment. *Marine Ecology Progress Series*, **238**, 249-279.
- Greathead, C.F., Donnan, D.W., Mair, J.M. & Saunders, G.R., 2007. The sea pens *Virgularia mirabilis*, *Pennatula phosphorea* and *Funiculina quadrangularis*: distribution and conservation issues in Scottish waters. *Journal of the Marine Biological Association*, **87**, 1095-1103.
- Griffith, K., Mowat, S., Holt, R.H., Ramsay, K., Bishop, J.D., Lambert, G. & Jenkins, S.R., 2009. First records in Great Britain of the invasive colonial ascidian *Didemnum vexillum* Kott, 2002. *Aquatic Invasions*, **4** (4), 581-590.
- Hatcher, A.M., 1998. Epibenthic colonization patterns on slabs of stabilised coal-waste in Poole Bay, UK. *Hydrobiologia*, **367**, 153-162.
- Hill, A.S., Brand, A.R., Veale, L.O. & Hawkins, S.J., 1997. Assessment of the effects of scallop dredging on benthic communities. Final Report to MAFF, Contract CSA 2332, Liverpool: University of Liverpool
- Hoare, R. & Wilson, E.H., 1977. Observations on the behaviour and distribution of *Virgularia mirabilis* O.F. Müller (Coelenterata: Pennatulacea) in Holyhead harbour. In *Proceedings of the Eleventh European Symposium on Marine Biology, University College, Galway, 5-11 October 1976. Biology of Benthic Organisms*, (ed. B.F. Keegan, P.O. Ceidigh & P.J.S. Boaden, pp. 329-337. Oxford: Pergamon Press. Oxford: Pergamon Press.
- Holme, N.A. & Wilson, J.B., 1985. Faunas associated with longitudinal furrows and sand ribbons in a tide-swept area in the English Channel. *Journal of the Marine Biological Association of the United Kingdom*, **65**, 1051-1072.
- Hovland, M. & Judd, A., 1988. *Seabed pockmarks and seepages: impact on geology, biology, and the marine environment*. London: Graham & Trotman.
- Hughes, D.J., 1998a. Sea pens & burrowing megafauna (volume III). An overview of dynamics and sensitivity characteristics for conservation management of marine SACs. *Natura 2000 report prepared for Scottish Association of Marine Science (SAMS) for the UK Marine SACs Project*, Scottish Association for Marine Science. (UK Marine SACs Project). Available from: <http://www.ukmarinesac.org.uk/publications.htm>
- Hughes, R.G., 1977. Aspects of the biology and life-history of *Nemertesia antennina* (L.) (Hydrozoa: Plumulariidae). *Journal of the Marine Biological Association of the United Kingdom*, **57**, 641-657.
- Irving R.A., Whittington M.W., Holt R.H.F., Stanwell-Smith D. & Northen K.O., 2007. Across-Wales Diving Monitoring Project

- Volume 1: Site Descriptions and Results 2004/05. Countryside Council for Wales, Bangor, 94 pp.
- Jennings, S. & Kaiser, M.J., 1998. The effects of fishing on marine ecosystems. *Advances in Marine Biology*, **34**, 201-352.
- Jensen, A.C., Collins, K.J., Lockwood, A.P.M., Mallinson, J.J. & Turnpenny, W.H., 1994. Colonization and fishery potential of a coal-ash artificial reef, Poole Bay, United Kingdom. *Bulletin of Marine Science*, **55**, 1263-1276.
- Jensen, P., Aagaard, I., Burke, R.A.J., Dando, P.R., Jørgensen, N.O., Kuijpers, A., Laier, T., O'Hara, S.C.M. & Schmaljohann, R., 1992. Bubbling reefs in the Kattegat: submarine landscapes of carbonate-cemented rocks support a diverse ecosystem at methane seeps. *Marine Ecology Progress Series*, **83**, 103-112.
- JNCC, 2008b. Offshore Special Area of Conservation: Scanner Pockmark. SAC Selection Assessment, ver 4.0. Joint Nature Conservation Committee, Peterborough. Available from <http://jncc.defra.gov.uk/page-6541>
- JNCC, 2015. The Marine Habitat Classification for Britain and Ireland Version 15.03. (20/05/2015). Available from <https://mhc.jncc.gov.uk/>
- Johnston, E.L. & Roberts, D.A., 2009. Contaminants reduce the richness and evenness of marine communities: a review and meta-analysis. *Environmental Pollution*, **157** (6), 1745-1752.
- Judd, A. & Hovland, M., 2007. *Seabed Fluid Flow: The Impact on Geology, Biology and the Marine Environment*. Cambridge: Cambridge University Press.
- Judd, A., 2005. The distribution and extent of methane-derived authigenic carbonate (MDAC) in the SEA6 area. *Technical report produced for Strategic Environmental Assessment - SEA2*. UK: Department of Trade and Industry, pp. 69.
- Judd, A., Croker, P., Tizzard, L. & Voisey, C., 2007. Extensive methane-derived authigenic carbonates in the Irish Sea. *Geo-Marine Letters*, **27** (2), 259.
- Keough, M.J. & Chernoff, H., 1987. Dispersal and population variation in the bryozoan *Bugula neritina*. *Ecology*, **68**, 199 - 210.
- Klawe, W.L. & Dickie, L.M., 1957. Biology of the bloodworm, *Glycera dibranchiata* Ehlers, and its relation to the bloodworm fishery of the Maritime Provinces. *Bulletin of Fisheries Research Board of Canada*, **115**, 1-37.
- Koopmans, M. & Wijffels, R.H., 2008. Seasonal Growth Rate of the Sponge *Haliclona oculata* (Demospongiae: Haplosclerida). *Marine Biotechnology*, **10** (5), 502-510.
- Last, K.S., Hendrick V. J., Beveridge C. M & Davies A. J., 2011. Measuring the effects of suspended particulate matter and smothering on the behaviour, growth and survival of key species found in areas associated with aggregate dredging. *Report for the Marine Aggregate Levy Sustainability Fund*,
- Lengyel, N.L., Collie, J.S. & Valentine, P.C., 2009. The invasive colonial ascidian *Didemnum vexillum* on Georges Bank - Ecological effects and genetic identification. *Aquatic Invasions*, **4**(1), 143-152.
- Levin, L.A., Ziebis, W., Mendoza, G.F., Growney-Cannon, V. & Walther, S., 2006. Recruitment response of methane-seep macrofauna to sulfide-rich sediments: An in situ experiment. *Journal of Experimental Marine Biology and Ecology*, **330** (1), 132-150. <https://doi.org/10.1016/j.jembe.2005.12.022>
- Linke, O., 1939. Die Biota des Jadebusenwatts. *Helgolander Wissenschaftliche Meeresuntersuchungen*, **1**, 201-348.
- Lutz, R.A., Shank, T.M., Fornari, D.J., Haymon, R.M., Lilley, M.D., Von Damm, K.L. & Desbruyeres, D., 1994. Rapid growth at deep-sea vents. *Nature*, **371**, 663. 10.1038/371663a0
- Mayer-Pinto, M. & Junqueira, A., 2003. Effects of organic pollution on the initial development of fouling communities in a tropical bay, Brazil. *Marine Pollution Bulletin*, **46** (11), 1495-1503.
- McCall, P.L., 1977. Community patterns and adaptive strategies of the infaunal benthos of Long Island Sound. *Journal of Marine Research*, **35**, 221-266.
- MES, 2010. *Marine Macrofauna Genus Trait Handbook*. Marine Ecological Surveys Limited. <http://www.genustraithandbook.org.uk/>
- Moore, P.G., 1977a. Inorganic particulate suspensions in the sea and their effects on marine animals. *Oceanography and Marine Biology: An Annual Review*, **15**, 225-363.
- Naranjo, S.A., Carballo, J.L., & Garcia-Gomez, J.C., 1996. Effects of environmental stress on ascidian populations in Algeciras Bay (southern Spain). Possible marine bioindicators? *Marine Ecology Progress Series*, **144** (1), 119-131.
- Nichols, D., 1984. An investigation of the population dynamics of the common edible sea urchin (*Echinus esculentus* L.) in relation to species conservation management. *Report to Department of the Environment and Nature Conservancy Council from the Department of Biological Sciences, University of Exeter*.
- O'Dea, A. & Okamura, B., 2000. Life history and environmental inference through retrospective morphometric analysis of bryozoans: a preliminary study. *Journal of the Marine Biological Association of the United Kingdom*, **80**, 1127-1128.
- O'Hara, S.C.M., Dando, P.R., Schuster, U., Bennis, A., Boyle, J.D., Chui, F.T.W., Hatherell, T.V.J., Niven, S.J. & Taylor, L.J., 1995. Gas seep induced interstitial water circulation: observations and environmental implications. *Continental Shelf Research*, **15** (8), 931-948. DOI [https://doi.org/10.1016/0278-4343\(95\)80003-V](https://doi.org/10.1016/0278-4343(95)80003-V)
- O'Reilly, S.S., Hryniewicz, K., Little, C.T.S., Monteys, X., Szpak, M.T., Murphy, B.T., Jordan, S.F., Allen, C.C.R. & Kelleher, B.P., 2014. Shallow water methane-derived authigenic carbonate mounds at the Codling Fault Zone, western Irish Sea. *Marine Geology*, **357**, 139-150. <https://doi.org/10.1016/j.margeo.2014.08.007>
- OSPAR, 2017. Composition and Spatial Distribution of Litter on the Seafloor. London: Oslo and Paris Commission (OSPAR). 2018(14/02/18).

<https://oap.ospar.org/en/ospar-assessments/intermediate-assessment-2017/pressures-human-activities/marine-litter/composition-and-spatial-distribution-litter-seafloor/>

- Ramirez-Llodra, E., Tyler, P.A., Baker, M.C., Bergstad, O.A., Clark, M.R., Escobar, E., Levin, L.A., Menot, L., Rowden, A.A., Smith, C.R. & Van Dover, C.L., 2011. Man and the Last Great Wilderness: Human Impact on the Deep Sea. *PLoS ONE*, **6** (8), e22588. 10.1371/journal.pone.0022588
- Riedel, B., Zuschin, M. & Stachowitsch, M., 2012. Tolerance of benthic macrofauna to hypoxia and anoxia in shallow coastal seas: a realistic scenario. *Marine Ecology Progress Series*, **458**, 39-52.
- Roberts, D.A., Johnston, E.L. & Knott, N.A., 2010b. Impacts of desalination plant discharges on the marine environment: A critical review of published studies. *Water Research*, **44** (18), 5117-5128.
- Rose, C.S. & Risk, M.J., 1985. Increase in *Cliona delitrix* infestation of *Montastrea cavernosa* heads on an organically polluted portion of the Grand Cayman fringing reef. *Marine Ecology*, **6** (4), 345-363.
- Rouse, G.W. & Pleijel, F., 2001. *Polychaetes*. New York: Oxford University Press.
- Ruso, Y.D.P., la Ossa Carretero, J.A.D., Casalduero, F.G. & Lizaso, J.L.S., 2007. Spatial and temporal changes in infaunal communities inhabiting soft-bottoms affected by brine discharge. *Marine environmental research*, **64** (4), 492-503.
- Ryland, J.S., 1976. Physiology and ecology of marine bryozoans. *Advances in Marine Biology*, **14**, 285-443.
- Ryland, J.S., Holt, R., Loxton, J., Spencer Jones, M. & Porter, J.S., 2014. First occurrence of the non-native bryozoan *Schizoporella japonica* Ortmann (1890) in Western Europe. *Zootaxa*, **3780** (3), 481-502.
- Sandrock, S., Scharf, E-M., von Oertzen, J.A., 1991. Short-term changes in settlement of micro- and macro-fouling organisms in brackish waters. *Acta Ichthyologica et Piscatoria*, **21**(Suppl.), 221-235.
- Sardá, R., Pinedo, S., Gremare, A. & Taboada, S., 2000. Changes in the dynamics of shallow sandy-bottom assemblages due to sand extraction in the Catalan Western Mediterranean Sea. *ICES Journal of Marine Science*, **57** (5), 1446-1453.
- Schönberg, C.H.L., 2015. Happy relationships between marine sponges and sediments—a review and some observations from Australia. *Journal of the Marine Biological Association of the United Kingdom*, 1-22.
- Sebens, K.P., 1985. Community ecology of vertical rock walls in the Gulf of Maine: small-scale processes and alternative community states. In *The Ecology of Rocky Coasts: essays presented to J.R. Lewis, D.Sc. (ed. P.G. Moore & R. Seed)*, pp. 346-371. London: Hodder & Stoughton Ltd.
- Sebens, K.P., 1986. Spatial relationships among encrusting marine organisms in the New England subtidal zone. *Ecological Monographs*, **56**, 73-96.
- Seffel, A., 2010. Present knowledge of submarine structures made by leaking gases in European Waters, and steps towards a monitoring strategy for the habitat. Ekologigruppen AB, Stockholm, 23 pp. http://www.ekologigruppen.se/Filer/uppladdning/submarine_structures.pdf
- Shaffer, P.L., 1983. Population ecology of *Heteromastus filiformis* (polychaeta: capitellidae). *Netherlands Journal of Sea Research*, **17**(1), 106-125.
- Shull, D.H., 1997. Mechanisms of infaunal polychaete dispersal and colonisation in an intertidal sandflat. *Journal of Marine Research*, **55**, 153-179.
- Sommer, C., 1992. Larval biology and dispersal of *Eudendrium racemosum* (Hydrozoa, Eudendriidae). *Scientia Marina*, **56**, 205-211. [Proceedings of 2nd International Workshop of the Hydrozoan Society, Spain, September 1991. Aspects of hydrozoan biology (ed. J. Bouillon, F. Cicognia, J.M. Gili & R.G. Hughes).]
- Sparks-McConkey, P.J. & Watling, L., 2001. Effects on the ecological integrity of a soft-bottom habitat from a trawling disturbance. *Hydrobiologia*, **456**, 73-85.
- Standing, J.D., 1976. Fouling community structure: effect of the hydroid *Obelia dichotoma* on larval recruitment. In *Coelenterate ecology and behaviour* (ed. G.O. Mackie), pp. 155-164. New York: Plenum Press.
- Stanley, J.A., Wilkens, S.L. & Jeffs, A.G., 2014. Fouling in your own nest: vessel noise increases biofouling. *Biofouling*, **30** (7), 837-844.
- Storr, J.F. 1976. Ecological factors controlling sponge distribution in the Gulf of Mexico and the resulting zonation. In *Aspects of Sponge Biology* (ed. F.W. Harrison & R.R. Cowden), pp. 261-276. New York: Academic Press.
- Thorson, G., 1946. Reproduction and larval development of Danish marine bottom invertebrates, with special reference to the planktonic larvae in the Sound (Øresund). *Meddelelser fra Kommissionen for Danmarks Fiskeri- Og Havundersøgelser, Serie: Plankton*, **4**, 1-523.
- Thorson, G., 1950. Reproductive and larval ecology of marine bottom invertebrates. *Biological Reviews*, **25**, 1-45.
- Trudgill, S.T. & Crabtree, R.W., 1987. Bioerosion of intertidal limestone, Co. Clare, Eire - 2: *Hiatella arctica*. *Marine Geology*, **74** (1-2), 99-109.
- Veale, L.O., Hill, A.S., Hawkins, S.J. & Brand, A.R., 2000. Effects of long term physical disturbance by scallop fishing on subtidal epifaunal assemblages and habitats. *Marine Biology*, **137**, 325-337.
- Whomersley, P., Wilson, C.M., Clements, A., Brown, C., Long, D., Leslie, A. & Limpenny, D., 2010b. Understanding the marine environment - seabed habitat investigations of submarine structures in the mid Irish Sea and Solan Bank Area of Search (AoS). *Joint Nature Conservation Committee, JNCC Report no. 430.*, Peterborough, 128 pp.

Wright, E.P., Kemp, K., Rogers, A.D. & Yesson, C., 2015. Genetic structure of the tall sea pen *Funiculina quadrangularis* in NW Scottish sea lochs. *Marine Ecology*, **36** (3), 659-667.

Wright, S.L., Rowe, D., Thompson, R.C. & Galloway, T.S., 2013. Microplastic ingestion decreases energy reserves in marine worms. *Current Biology*, **23** (23), R1031-R1033.