

Scallop (Queen) Dredge on Subtidal Bedrock Reef

Introduction

The Assessing Welsh Fisheries Activities Project is a structured approach to determine the impacts from current and potential fishing activities, from licensed and registered commercial fishing vessels, on the features of Marine Protected Areas.

1. Gear and Feature	Scallop (Queen) Dredge on Subtidal Bedrock Reef
2. Risk Level	Purple (High risk)
3. Description of Feature: (see Annex 1 for further information on description).	<p>Bedrock is normally an unbroken solid rock which is often found underlying sediments in the marine environment. When exposed as an outcrop on the seabed, it is classed as a subtidal bedrock reef. It can often be found in a matrix of cobbles and boulders (JNCC¹).</p> <p>For the purposes of the Assessing Welsh Fishing Activities Project the ‘subtidal bedrock reef’ assessment has been separated from the ‘boulder and cobble’ reef assessment. While the assessments share a number of supporting communities/biotopes that are subject to the same effects from mobile fishing gear, the effects of trawling on the structure of subtidal bedrock and boulder/cobble reefs could vary. An explanation of how subtidal bedrock reef and subtidal boulder/cobble reef have been separated is detailed in Annex 1. A list of biotopes commonly associated with subtidal bedrock reef are listed in Annex 2.</p> <p>Subtidal bedrock reef communities can vary according to a number of factors such as rock type, topographical features (e.g. vertical rock walls, gully and canyon systems and outcrops from sediment) and exposure to wave action and tidal currents (JNCC¹). Areas with strong tidal flows are usually dominated by a robust turf of animals such as sponges and anemones including species like the oaten pipes hydroid <i>Tubularia spp.</i> (JNCC²). For example, the Menai Strait and Milford</p>

Haven both have subtidal bedrock communities dominated by sponge species, which are thought to be partly as a result of the strong tidal flows and shelter from wave action (CCW, 2009a; CCW, 2009b). In contrast, foliose red seaweeds may dominate in shallower water (Stamp & Marshall, 2015), and areas that are extremely exposed to wave action tend to have fewer species and may be dominated by species like keel worms, anemones and encrusting sponges (JNCC³).

There are various subtidal bedrock reef communities. The most commonly occurring biotopes found on subtidal bedrock reefs in Welsh waters are mixed faunal turf communities (CR.HCR.XFa), bryozoan turf and erect sponges on tide-swept circalittoral rock (CR.HCR.XFa.ByErSp), foliose red seaweeds on exposed lower infralittoral rock (IR.HIR.KFaR.FoR) and sponges and anemones on vertical circalittoral bedrock (CR.HCR.XFa.SpAnVt). Species associated with bedrock reef that are known to be particularly fragile include the pink sea fan *Eunicella verrucosa* and branching sponges such as *Axinella disimillis*.

Other physical, chemical and biological factors such as; depth, water clarity, salinity and temperature can have influence on reef communities (JNCC¹). Bedrock reefs in the shallow subtidal area, where there are good light levels, support a wide range of plants and animals dominated by kelps (most commonly *Laminaria hyperborea*, *Laminaria digitata* and *Alaria esculenta*) and other seaweeds. In deeper water, where the light levels are lower, the emphasis is towards animal-dominated communities with fauna typically including, sponges, corals, hydroids, anemones, sea squirts, echinoderms and bryozoans (JNCC¹). Suspended sediments can also influence community structures with sediments in the water column limiting light availability, potentially causing scouring or effecting the availability of food supply (CCW, 2009c). The temperature of the water can also have an important influence (O'Connor *et al*, 2007). In the UK, there is a marked biogeographical trend in species composition related to

	<p>temperature, with warmer water, temperate species such as the pink sea-fan (<i>Eunicella verrucosa</i>) occurring in south Wales (CCW, 2009b).</p> <p>In comparison with other areas of the UK, Welsh reefs have relatively low densities of the urchin <i>Echinus esculentus</i>, which results in low grazing pressures and consequently particularly luxuriant and diverse red algal turfs in some areas (CCW, 2009c).</p>
<p>4. Description of Gear</p>	<p>Queen scallops (<i>Aequipecten opercularis</i>) are predominantly targeted using towed fishing gear, either in the form of skid dredges (modified Newhaven dredges) or modified otter trawls.</p> <p>Queen scallops are more active swimmers than king scallops and do not recess into the seabed (Brand, 2006). Dredges and otter trawls take advantage of the natural propensity of queen scallops to swim up into the water column when disturbed, rather than relying on extraction of the scallops from the sediment as is the case for Newhaven dredges (Beukers-Stewart & Beukers-Stewart, 2009).</p> <p>A modified Newhaven dredge can be about 1.95m wide, often with a higher front opening. Instead of metal teeth it can have a rubber lip or sometimes the front part of the dredge consists of a metal grid mounted on four rubber rollers, two on each side of the grid. Alternatively, the tooth bar is replaced with a tickler chain. The modified dredge is normally fitted with skis or skids on either side designed to run along the top of the seabed. The dredge has a traditional metal belly bag with a mesh size of 60mm to retain the queen scallops (Humphey, 2009).</p> <p>Traditional toothed king scallop dredges are occasionally used to target queen scallops, these dredges are approximately 0.76m wide, with a chain mail belly bag and a 60mm mesh. Each dredge bar usually has 17 metal teeth of around 6cm in length on it (Hinz <i>et al</i>, 2009). The amount of dredges per side of the vessel can vary between 1 and 16 depending on the size and power of the vessel.</p>

	<p>The choice of skid dredges or otter trawls is largely governed by the nature of the substrate on different fishing grounds, with skid dredges being more effective in rough/coarse sediment areas and trawls in sandy/muddy areas (Vause <i>et al</i>, 2007).</p>
<p>5. Assessment of Impact Pathways:</p> <ol style="list-style-type: none"> 1. Damage to a designated habitat feature (including through direct physical impact, pollution, changes in thermal regime, hydrodynamics, light etc.). 2. Damage to a designated habitat feature via removal of, or other detrimental impact on, typical species. 	<p>There is a lack of studies specifically investigating the impacts of scallop (queen) dredge gear on the associated biotopes listed in Annex 2; therefore it is necessary to widen the research parameters to include other comparable bottom contacting mobile gear.</p> <ol style="list-style-type: none"> 1. Demersal beam trawl gear can have a direct physical effect on the seabed wherever the beams, shoes, mats, nets and chains make contact. Ways in which gear affects the seabed can be classified as: scraping and ploughing; sediment resuspension; and physical destruction (Jones, 1992). <p>Boulcott & Howell (2011) conducted experimental Newhaven scallop dredging over a circalittoral rock habitat in the Kilbrannan Sound, Scotland. The results showed that a single trawl of a scallop dredge left clear discernible scrape marks in the bedrock which were evident in 5 of the 23 photographic quadrats. However, these direct impacts are not thought to negatively impact the integrity of the rock of subtidal bedrock feature.</p> <p>Jennings <i>et al.</i> (2001) discussed the direct effects of towed fishing gear on the substratum and conclude that habitat alteration may be permanent if bedrock formations become fragmented. However, the habitat would still remain a subtidal bedrock reef habitat but it may potentially provide opportunities for new flora and fauna to colonise.</p> <p>In conclusion, direct contact between scallop (queen) dredge gear and subtidal bedrock reef is not thought to cause a significant impact to the integrity of the subtidal bedrock reef itself.</p> <ol style="list-style-type: none"> 2. Demersal mobile fishing gear reduces habitat complexity by: removing emergent epifauna, smoothing sedimentary bedforms, and removing or scattering non target taxa that produce structure (Auster &

Langton 1999; Jones 1992). Subtidal bedrock reef sites are thought to be sensitive to towed demersal gear effects, as they often are abundant in encrusting and erect biota that are easily damaged by bottom trawling (Kaiser *et al*, 2002).

Bottom fishing has the potential to directly displace, injure, remove, or destroy flora and fauna colonies (Van Dolah *et al*, 1987; Sainsbury *et al*, 1997; Freese *et al*, 1999; Fosså *et al*, 2002; Wassenberg *et al*, 2002). Injuries, which may lead to delayed mortality (Freese & Wing, 2003), demand costly resources for regeneration, potentially impairing colony growth and sexual reproduction (Rinkevich, 1996; Henry & Kenchington, 2004), and hence may ultimately limit population recruitment.

The solidity of rock and the fractal complexity of its surface provide an abundance of stable, niche habitats exploited by a wide diversity of species, leading to the modern perception that rocky reefs habitats have high biodiversity (Kostylev *et al*, 2005). Exclusive communities live in crevices and often do not protrude above the surface of the rock, they are are not thought to be at risk of damage from towed demersal gear. However, sensitive species that often characterise this feature occur on the surface of the subtidal bedrock reef and have limited protection from abrasion (Connor *et al*, 2004).

The Marine Life Information Network (MarLIN) considers the sensitivity of biotopes/components of biotopes to the impacts from general abrasion. In the following analysis the MarLIN sensitivity assessments (Annex 2) are utilised and supported where further scientific literature is available on the specific interactions.

Communities of flora and fauna that live in or on caves, overhangs, vertical walls and very large immovable boulders can be sensitive to abrasion. However, the operation of towed demersal gears prevents the gear from interacting with these subtidal bedrock reef habitat types. Therefore these features are considered as low sensitivity to abrasion from towed demersal gear.

Sponges

A number of studies have concluded that the effects of single trawl event from towed demersal gear on sponges led to a significant proportion of sponges being damaged and/or loosened and that recovery was slow (Van Dolah *et al*, 1987; Tilmant, 1979; Freese *et al*, 1999; Freese, 2001; Boulcott and Howell, 2011). Tilmant (1979) recorded that the a recovery was ongoing but not complete 11 months after a trawl event. Freese revisited a site one year after a trawl event and found no signs of sponge regrowth or recovery.

Little information on sponge longevity and resilience exists. Individual sponges are usually hermaphrodites (Hayward & Ryland, 1995) and reproduction can be asexual (e.g. budding) or sexual (Naylor, 2011). Growth and reproduction are generally seasonal (Hayward & Ryland, 1995) with sponge rejuvenation possible from fragments of sponge (Fish & Fish, 1996). Some sponges are known to be highly resilient to physical damage with an ability to survive severe damage, regenerate and reorganize to function fully again, however, this recoverability varies between species (Coleman *et al*, 2013; Wulff, 2006). The majority of the literature agrees that a single trawl could damage or remove 25-75% of sponges. Therefore it can be presumed that multiple trawl events will increase this level of impact.

Sponges characterise biotopes such as: CR.HCR.XFa.ByErSp and CR.HCR.XFa.ByErSp.Sag

Anthozoans

Eunicella verrucosa is a sessile epifaunal species and is likely to be severely damaged by heavy mobile gears, such as scallop dredging (MacDonald *et al*, 1996; Tinsley, 2006; Hinz *et al*, 2011; Hiscock, 2007). *Eunicella* grows very slowly in British waters, approximately 1cm per year (Bunker, 1986; Picton & Morrow, 2005). Recovery following an abrasion event, such as trawling, is likely to take over 4 years (Coma *et al*, 2006; Sheehan *et al*, 2013). Importantly *Eunicella verrucosa* larvae are thought to generally settle near the parent

(Hiscock, 2007; Weinberg & Weinberg, 1979), therefore recovery is most likely if fecund mature species are left after a fishing event.

Boulcott & Howell (2011) conducted experimental Newhaven scallop dredging (a source of abrasion) over a circalittoral rock habitat in the sound of Jura, Scotland and recorded the damage to the resident community. Damage to circalittoral rock fauna was of an incremental nature, with loss of species such as *Alcyonium digitatum* and faunal turf communities increasing with repeated trawls. *Alcyonium digitatum*, *Tubularia indivisa* plus the anthozoan community are sedentary species that would likely suffer from the effects of abrasion (Stamp, 2015). The Marlin resilience assessment of the CR.HCR.FaT.CTub.Adig biotope is largely based on the time taken for *Alcyonium digitatum* to recover (approximately 5 years). Without the recovery of this species, the biotope would change (Stamp, 2015).

Caryophyllia smithii is a small (max 3 cm across) solitary coral common within tide swept sites of the UK (Wood, 2005). Fowler & Laffoley (1993) suggests that *Caryophyllia smithii* is a slow growing species (0.5-1mm in horizontal dimension of the corallum per year). This suggests that damage from a single trawl, however minor, could be long lasting.

Sagartia elegans, *Urticina felina*, *Metridium senile*, *Actinothoe sphyrodeta* and *Corynactis virdis* can colonize bare surfaces through a-sexual reproduction within 1 year but may take up to 5 years to establish mature populations (Wood, 2005). If after a single trawling event, members of these species remained within the community it is likely they could recolonize without the need for larval recruitment.

Some of the anthozoan community could potentially re-cover relatively quickly from damage caused by trawling, however if the assemblage is completely removed from the habitat, recovery would be less likely. Re-establishment of typical biomass will be driven by surviving individuals as well as recruitment (Stamp, 2015).

Anthozoans characterise biotopes such as: CR.HCR.XFa.ByErSp.Eun,

CR.HCR.FaT.CTub.Adig and CR.MCR.EcCr.UrtScr

Bryozoans

Typical bryozoans include *Flustra foliacea*, which although flexible, physical disturbance by passing mobile gear is likely to damage fronds and remove some colonies. Colonies on hard substrata are probably less vulnerable to fishing activity but would probably be damaged or partially removed (Bullimore, 1985; Jennings & Kaiser, 1998).

Silén (1981) reported that experimental removal of a notch in the frond of *Flustra foliacea* was repaired within 5 -10 days. The newly formed margin where the notch has been removed grew at normal rates (4-5 zooid lengths per month). Additionally the removal of one layer of the bilaminar frond, experimentally (Silén, 1981) or by predators (Stebbing, 1971) was repaired with similar rapidity. It was noted that the undamaged layer of the frond stopped growing while the damaged area was being repaired (Silén, 1981).

Bugula spp. and other bryozoan species exhibit multiple generations per year, that involve good local recruitment, rapid growth and reproduction. Bryozoans are often opportunistic, fouling species that colonize and occupy space rapidly. For example, hydroids would probably colonize within 1-3 months and return to their original cover rapidly; while *Bugula* species have been reported to colonize new habitats within 6 -12 months. However, *Bugula* has been noted to be absent from available habitat even when large populations are nearby (Castric-Frey, 1974; Keough & Chernoff, 1987), suggesting that recruitment may be more sporadic (Tyler-Walters, 2005).

The bryozoan community could potentially re-cover relatively quickly from damage caused by a single trawling episode, however if the assemblage is subjected to repeated trawling and/or completely removed from the habitat, recovery would take longer relying on re-colonization rates and good local recruitment from surviving communities (Stamp, 2015).

Bryozoans characterise biotopes such as: CR.HCR.XFa.FluCoAs and CR.MCR.EcCr.FaAICr.Flu

Hydrozoans

Hydroids are thought of as early colonizers of bare surfaces (Whomersley & Picken, 2003; Zintzen *et al*, 2008; Hiscock *et al*, 2010) with *Tubularia spp.* opportunistically often the first to colonize and reaching sexual maturity rapidly (Hughes, 1983).

Tubularia indivisa is a short lived, common athecate hydroid species, and recruitment is seasonally variable with settlement peaking in early spring, however other smaller recruitment events occur within summer and autumn (Hughes, 1983).

The hydrozoan community could potentially re-cover relatively quickly from damage caused by a single trawling episode, however if the assemblage is subjected to repeated trawling and/or completely removed from the habitat, recovery would take longer relying on re-colonization rates (which are thought to be high in hydroids) and good local recruitment from surviving communities.

Hydrozoans characterise biotopes such as: CR.MCR.CFaVS.CuSpH and CR.HCR.FaT.CTub.Adig

Kelps and Seaweeds

Physical disturbance by towed demersal gear is likely to remove a proportion of macroalgae, such as fucoids and laminarians. The kelps *Laminaria spp.* act as ecosystem engineers (Jones *et al*, 1994; Smale *et al*, 2013) by altering; light levels (Sjøtun *et al*, 2006), physical disturbance (Connell, 2003), sedimentation rates (Eckman *et al*, 1989) and water flow (Smale *et al*, 2013), which can profoundly alter the physical environment for fauna and flora in close proximity. *Laminaria hyperborea* biotopes increase the three dimensional complexity of unvegetated rock (Norderhaug, 2004; Norderhaug *et al*, 2007; Norderhaug & Christie, 2011; Gorman *et al*, 2012; Smale *et al*, 2013)

and support high local diversity, abundance and biomass of epi/benthic species (Smale *et al*, 2013), and serve as a nursery ground for a number of species. Kelp is also an important species as a primary producer (Kaiser, 2011), food resource (Kaiser, 2011) and provides bird foraging habitat (Iken, 2012). Christie *et al*. (1998) suggested that kelp habitats were relatively resistant to the direct disturbance/removal of the *Laminaria hyperborea* canopy.

Recruitment of kelps following disturbance can be influenced by the proximity of mature kelp beds producing viable zoospores to the disturbed area (Kain, 1979; Fredriksen *et al*, 1995). Kain (1964) investigated the removal of kelp through trawling and found that the associated holdfast communities recovered in 6 years, however the epiphytic stipe community did not fully recover within the same time period. Even though the associated holdfast and stipe colonies eventually die as the substratum rots, over a few weeks at sea they are likely to shed thousands of larvae, and seaweed rafts are now seen as important dispersal agents (Hayward & Ryland, 2017).

Seaweed communities (both red and brown) are likely to be affected by entanglement with the trailing nets of the beam trawl. This can cause tearing of the macroalgae. Recoverability is dependent on the remaining proportion of individuals, if the holdfast and/or stipe remain, regrowth is likely to be rapid in most species. However, if the whole plant is removed, recolonization is reliant on reproduction of nearby colonies. If nearby seaweed communities survive a trawling episode, their fitness (e.g. growth rates and reproductive output) may be compromised by the level of damage sustained during trawling. Therefore, surviving seaweed communities will be less efficient at aiding recolonization of adjacent lost individuals (Iken, 2012).

Kelps and seaweeds can recover quickly from superficial tearing however repeated trawling and high impact damage, to the stipe or holdfast, could take more than 6 years to recover. Damaged individuals will be less efficient at aiding recolonization.

Kelps and seaweeds characterise biotopes such as: IR.HIR.KFaR.LhypR, IR.LIR.K.LhypLsac, IR.MIR.KT.FilRVS and IR.MIR.KT.XKT

Ascidians

The ascidians are epifaunal and physical disturbance is likely to cause damage with mortality likely. Emergent epifauna are generally very intolerant of disturbance from fishing gear (Jennings & Kaiser, 1998). However, studies have shown *Ascidia spp.* to become more abundant following disturbance events (Bradshaw *et al*, 2000). Ascidians are likely to be significantly affected by abrasion caused by towed demersal fishing gear, although, given their high resilience, they are likely to recover quickly (Stamp, 2015).

Ascidians characterise biotopes such as: IR.FIR.SG.DenCcor

Sabellaria spp.

(Detailed assessments of *Sabellaria spp.* reef have been undertaken separately).

Fishing with scallop (queen) dredge gear can negatively impact on *Sabellaria alevolata* and *Sabellaria spinulosa* reefs through partial or total damage and/or removal of the reef structure through abrasion and ploughing and through removal/damage of typical species. Recovery will be dependant on local factors such as season of impact, larval supply, environmental factors, condition of reef etc. Although there is a potential for rapid recovery of a partially damaged reef, and a much slower recovery for heavily impacted reefs, the conditions to support recovery are not guaranteed. (AWFA, 2017a).

Sabellaria spp. characterise biotopes such as: CR.MCR.CSab

Mussels

(Detailed assessments of Subtidal Mussel Bed on Rock have been undertaken separately).

Fishing with scallop (queen) dredge gear directly on subtidal mussel bed on rock features is likely to be lethal by crushing or be indirectly damaging by weakening or breaking of the byssus threads, making them prone to becoming unattached. While recovery is possible this is dependant on local environmental factors such as larval availability, tidal influence and the extent of the remaining bed. Recovery would also be less likely in periods of prolonged fishing. The damage or removal of a mussel bed would also result in the damage or removal of attached species. (AWFA, 2017b).

Mussels characterise biotopes such as: CR.MCR.Cmus.Mdis, CR.MCR.Cmus.CMyt and IR.LIR.IFaVS.MytRS

Other habitat forming species

The urchin *Echinus esculentus* characterises biotopes such as: IR.MIR.KR.Lhyp.GzPk and IR.MIR.KR.Lhyp.GzFt and fluctuations in their numbers may give foliose seaweeds a chance to re-grow periodically. There may be a change in community structure when grazing pressure decreases, although recoverability is probably high. However, recruitment can be sporadic or annual depending on locality and factors affecting larval pre-settlement and post-settlement survival (Lewis & Nichols, 1980).

Brittlestars characterise biotopes such as: CR.MCR.EcCr.CarSp.Bri and CR.MCR.EcCr.FaAICr.Bri and the removal of the dense brittlestar beds may change the community structure. Brittlestar beds have been assessed under this project separately (AWFA, 2017c).

In conclusion, scallop (queen) dredge gear could cause an abrasive pressure upon a number of the subtidal bedrock reef biotopes listed in Annex 2. Any activity that physically abrades the faunal crust is likely to result in localized damage. Increase in scour or other abrasion events are likely to remove sponge, ascidian and anemone components. Dredging can physically remove or damage much of the macro-epibenthic fauna. Small colonies that may survive a single dredge are unlikely to survive repeated dredges. On a comparison between cold

	<p>and warm water experiments, impacts of trawling are much more persistent on cold water species due to the slower growth/regeneration rates. Damaged or lost individuals are likely to be replaced by early colonizers, which could change the biotope. Given the slow growth rates and long lifespans of the rich, diverse fauna in Welsh waters, it is likely to take many years for cold water communities to recover if adversely affected by physical damage.</p> <p>Impact from scallop (queen) dredge gear on flora is likely to include tearing and/or displacement of individuals or communities which, depending on the remaining proportion of the flora, could recover quickly. Recovery is likely to be led by fast colonising individuals such as <i>Sagartia elegans</i>, <i>Urticina felina</i>, <i>Metridium senile</i>, <i>Actinothoe sphyrodeta</i> and <i>Corynactis virdis</i>. The majority of the epifauna species often rely on adjacent colonies for recolonization, however, recovery is likely to be slower if the adjacent colonies are degraded by dredging.</p>
<p>6. MPAs where feature exists</p>	<p>Pembrokeshire Marine SAC</p> <p>The bedrock reefs in this site are distributed around the Pembrokeshire Islands and in shallow waters along most of the coast (generally to a distance of around 2Nm) with the exception of the central part of St Brides Bay, the section of Milford Haven between South Hook Point and the mouth of Pembroke River and the upper part of the Daugleddau and the Cleddau. There are records of the Section 7 habitat “Fragile sponges and anthozoans” around the North Pembrokeshire Islands, Skomer, Skokholm, north-west of St Ann’s Head and a single record at Dockyard Bank in Milford Haven and another west of Abereddy. There are other, lower confidence, records in the mouth of Milford Haven and off Linney Head.</p>
	<p>Pen Llyn a’r Sarnau SAC</p> <p>The majority of bedrock reef in the SAC is around the Llyn Peninsula and Bardsey Island, generally within 1 or 2Nm of the coast. The habitat is common in this area. There are records of the Section 7 habitat “Fragile sponges and anthozoans” around Bardsey Island and the adjacent headland and also on the north coast of the Llyn north of Porthysgaden, around Maen Mellt and south of Porth Oer.</p>

	Menai Strait and Conwy Bay SAC	Bedrock reef has been recorded in the central tideswept part of the Menai Strait, around Puffin Island, North to Red Wharf Bay, around the Great and Little Ormes and in the north of the site near Moelfre.
	Cardigan Bay SAC	The distribution of bedrock reef is patchy and all records are close to the coast (within 1.5Nm). Most of the records are from the area surrounding Cardigan Island, with further records along the coast including Ynys Lochtyn. The Section 7 habitat “Fragile sponges and anthozoans” has been recorded off New Quay Head.
	Carmarthen Bay and Estuaries SAC	Bedrock reef occurs within the large shallow inlet and bay feature of the SAC off Caldey Island and East of Tenby, plus a small amount off Worms Head.

7. Conclusion

The information presented above indicates that the action of fishing with scallop (queen) dredge gear directly on subtidal bedrock reef could potentially cause a fragmenting of the bedrock formation in some instances. However this impact would not change the physical structure of the subtidal bedrock feature itself. The effect of scallop (queen) dredge gear during the initial interaction or from repeated fishing events is likely to cause damage, which could be long-lasting and lethal, to the species which occupy the subtidal bedrock reef habitat. While rapid recovery is possible for some species, this is often reliant on adjacent communities for recolonization. Fishing with scallop (queen) dredge gear could potentially remove the majority of existing individuals, instigating a recolonization led by early colonisers such as *Sagartia elegans*, *Urticina felina*, *Metridium senile*, *Actinothoe sphyrodeta* and *Corynactis virdis*, which could change the species composition and potentially the biotope.

8. References

- Auster, P.J., Langton, R.W. (1999). The effects of fishing on fish habitat. In: Benaka L (ed) Fish habitat essential fish habitat (EFH) and rehabilitation. Am Fish Soc 22:150-187
- AWFA. (2017a). Beam Trawl on *Sabellaria spp.* reef. Assessing Welsh Fishing Activities project assessments.
- AWFA. (2017b). Beam Trawl on Subtidal Mussel Bed on Rock. Assessing Welsh Fishing Activities project assessments.
- AWFA. (2017c). Beam Trawl on Brittlestar Beds. Assessing Welsh Fishing Activities project assessments.
- Beukers-Stewart B.D. & Beukers-Stewart, J.S. (2009). Principles for the management of inshore scallop fisheries around the United Kingdom. Report to Natural England, Countryside Council for Wales and Scottish Natural Heritage. University of York. 57pp.
- Boulcott, P. & Howell, T.R.W. (2011). The impact of scallop dredging on rocky-reef substrata. Fisheries Research (Amsterdam), 110 (3), 415-420.

- Bradshaw, C., Veale, L.O., Hill, A.S. & Brand, A.R. (2000). The effects of scallop dredging on gravelly seabed communities. In: Effects of fishing on non-target species and habitats (ed. M.J. Kaiser & de S.J. Groot), pp. 83-104. Oxford: Blackwell Science.
- Brand, A.R. (2006). Scallop Ecology: Distributions and Behaviour. In: Shumway S, Parsons GJ (eds) *Scallops: Biology, Ecology and Aquaculture*. Elsevier, Amsterdam, p 1460
- Bullimore, B. (1985). An investigation into the effects of scallop dredging within the Skomer Marine Reserve. *Report to the Nature Conservancy Council by the Skomer Marine Reserve Subtidal Monitoring Project, S.M.R.S.M.P. Report*, no 3., Nature Conservancy Council.
- Bunker, F. (1986). Survey of the Broad sea fan *Eunicella verrucosa* around Skomer Marine Reserve in 1985 and a review of its importance (together with notes on some other species of interest and data concerning previously unsurveyed or poorly documented areas). Volume I. *Report to the NCC by the Field Studies Council*.
- Castric-Fey, A. (1974). *Les peuplements sessiles du benthos rocheux de l'archipel de Glenan (Sud-Bretagne). Ecologie descriptive and experimentale*. , Ph. D. thesis, Université de Bretagne Occidentale, L' Université Paris, Paris, France.
- CCW. (2009a). Countryside Council for Wales. Menai Strait and Conwy Bay European Marine Site – Advice in fulfilment of regulation 33 of the conservation (natural habitats, &c.) regulations 1994.
- CCW. (2009b). Countryside Council for Wales. Pembrokeshire Marine European Marine Site – Advice in fulfilment of regulation 33 of the conservation (natural habitats, &c.) regulations 1994.
- CCW. (2009c). Countryside Council for Wales. Pen Llyn a'r Sarnau European Marine Site – Advice in fulfilment of regulation 33 of the conservation (natural habitats, &c.) regulations 1994.
- Christie, H., Fredriksen, S. & Rinde, E. (1998). Regrowth of kelp and colonization of epiphyte and fauna community after kelp trawling at the coast of Norway. *Hydrobiologia*, **375/376**, 49-58.
- Coleman, R.A., Hoskin, M.G., von Carlshausen, E. & Davis, C.M. (2013). Using a no-take zone to assess the impacts of fishing: Sessile epifauna appear insensitive to environmental disturbances from commercial potting. *Journal of Experimental Marine Biology and Ecology*, **440**, 100-107.
- Coma, R., Linares, C., Ribes, M., Diaz, D., Garrabou, J. & Ballesteros, E. (2006). Consequences of a mass mortality in populations of *Eunicella singularis* (Cnidaria: Octocorallia) in Menorca (NW Mediterranean). *Marine Ecology Progress Series*, **331**, 51-60.
- Connell, S.D. (2003). Negative effects overpower the positive of kelp to exclude invertebrates from the understory community. *Oecologia*, **137**(1), pp.97-103.
- Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B. (2004). The Marine Habitat Classification for Britain and Ireland. Version 04.05. Joint Nature Conservation Committee, Peterborough. www.jncc.gov.uk/MarineHabitatClassification.
- Eckman, J.E., Duggins, D.O. & Sewell, A.T. (1989). Ecology of under story kelp environments. I. Effects of kelps on flow and particle transport near the bottom. *Journal of Experimental Marine Biology and Ecology*, **129**(2), pp.173-187.
- Fish, J.D. & Fish, S. (1996). *A student's guide to the seashore*. Cambridge: Cambridge University Press.
- Fowler, S. & Laffoley, D. (1993). Stability in Mediterranean-Atlantic sessile epifaunal communities at the northern limits of their range. *Journal of Experimental Marine Biology and Ecology*, **172** (1), 109-127.

- Fosså, J.H., Mortensen, P.B., Furevik, D.M. (2002). The deep-water coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts. *Hydrobiologia* 471:1–12
- Fredriksen, S., Sjøtun, K., Lein, T.E. & Rueness, J. (1995). Spore dispersal in *Laminaria hyperborea* (Laminariales, Phaeophyceae). *Sarsia*, **80** (1), 47-53.
- Freese, J.L. (2001). Trawl-induced damage to sponges observed from a research submersible. *Marine Fisheries Review*, **63** (3), 7-13.
- Freese, J.L. & Wing, B.L. (2003). Juvenile Red Rockfish, *Sebastes* sp., Associations with Sponges in the Gulf of Alaska. *Marine Fisheries Review*, 65(3), pp. 38-42
- Freese, J.L., Auster, P.J., Heifetz, J. & Wing, B.L. (1999). Effects of trawling on seafloor habitat and associated invertebrate taxa in the Gulf of Alaska. *Marine Ecology Progress Series*, **182**, 119-126.
- Gorman, D., Bajjouk, T., Populus, J., Vasquez, M. & Ehrhold, A. (2013). Modeling kelp forest distribution and biomass along temperate rocky coastlines. *Marine Biology*, **160** (2), 309-325.
- Hayward, P.J. & Ryland, J.S. (ed.) (1995). *Handbook of the marine fauna of North-West Europe*. Oxford: Oxford University Press.
- Hayward, P.J. & Ryland, J.S. (ed.) (2017). *Handbook of the marine fauna of North-West Europe*. Oxford: Oxford University Press.
- Henry, L-A. & Kenchington, E.L. (2004). Ecological and genetic evidence for impaired sexual reproduction and induced clonality in the hydroid *Sertularia cupressina* (Cnidaria: Hydrozoa) on commercial scallop grounds in Atlantic Canada. *Marine Biology*, 145(6), 1107-1118.
- Hinz, H., Tarrant, D., Ridgeway, A., Kaiser, M.J. & Hiddink, J.G. (2011). Effects of scallop dredging on temperate reef fauna. *Marine Ecology Progress Series*, **432**, 91-102.
- Hiscock, K. (2007). *Eunicella verrucosa* Pink sea fan. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: <http://www.marlin.ac.uk/species/detail/1121>
- Hiscock, K., Sharrock, S., Highfield, J. & Snelling, D. (2010). Colonization of an artificial reef in south-west England—ex-HMS ‘Scylla’. *Journal of the Marine Biological Association of the United Kingdom*, 90 (1), 69-94.
- Hughes, R. (1983). The life-history of *Tubularia indivisa* (Hydrozoa: Tubulariidae) with observations on the status of *T. ceratogyne*. *Journal of the Marine Biological Association of the United Kingdom*, 63 (02), 467-479.
- Humphey, M. (2009). Testing Materials used in Queen Scallop dredge Construction. SEAFISH report: SR612
- Iken, K. (2012). Grazers On Benthic Seaweeds. *Seaweed Biology: Novel Insights into Ecophysiology, Ecology and Utilization*. 157-177.
- Jennings, S., Kaiser, M.J., Reynolds, J.D. (2001). *Marine Fisheries Ecology*. Blackwell Science, Oxford. 432p
- Jennings, S. & Kaiser, M.J. (1998). The effects of fishing on marine ecosystems. *Advances in Marine Biology*, **34**, 201-352.
- JNCC¹ - <http://jncc.defra.gov.uk/ProtectedSites/SACselection/habitat.asp?FeatureIntCode=H1170>
- JNCC² - <http://jncc.defra.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00002121>
- JNCC³ - <http://jncc.defra.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00001531>
- Jones, B. (1992). Environmental impact of trawling on the seabed: A review, *New Zealand Journal of Marine and Freshwater Research*, 26:1, 59-67
- Jones, C.G., Lawton, J.H. & Shackak, M. (1994). Organisms as ecosystem engineers. *Oikos*, **69**, 373-386.

- Jones, L.A., Hiscock, K. & Connor, D.W. (2000). Marine habitat reviews. A summary of ecological requirements and sensitivity characteristics for the conservation and management of marine SACs. *Joint Nature Conservation Committee, Peterborough. (UK Marine SACs Project report.)*. Available from: <http://www.ukmarinesac.org.uk/pdfs/marine-habitats-review.pdf>
- Kain, J.M. (1964). Aspects of the biology of *Laminaria hyperborea* III. Survival and growth of gametophytes. *Journal of the Marine Biological Association of the United Kingdom*, **44** (2), 415-433.
- Kain, J.M. (1979). A view of the genus *Laminaria*. *Oceanography and Marine Biology: an Annual Review*, **17**, 101-161.
- Kaiser, M.J. (2011). *Marine ecology: processes, systems, and impacts*. Oxford University Press.
- Kaiser, M.J., Collie, J.S., Hall, S.J., Jennings, S., Poiner, I.R. (2002). Modification of marine habitats by trawling activities: prognosis and solutions. *Fish Fish.* **3**, 114–136.
- Keough, M.J. & Chernoff, H. (1987). Dispersal and population variation in the bryozoan *Bugula neritina*. *Ecology*, **68**, 199 - 210.
- Kostylev, V.E., Erlandsson, J., Ming, M.Y., Williams, G.A. (2005). The relative importance of habitat complexity and surface area in assessing biodiversity: fractal application on rocky shores. *Ecological Complexity* **2**, 272–286.
- Lewis, G.A. & Nichols, D. (1980). Geotactic movement following disturbance in the European sea-urchin, *Echinus esculentus* (Echinodermata: Echinoidea). *Progress in Underwater Science*, **5**, 171-186.
- MacDonald, D.S., Little, M., Eno, N.C. & Hiscock, K. (1996). Disturbance of benthic species by fishing activities: a sensitivity index. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **6** (4), 257-268.
- Naylor. P. (2011). *Great British Marine Animals, 3rd Edition*. Plymouth. Sound Diving Publications
- Norderhaug, K.M. (2004). Use of red algae as hosts by kelp-associated amphipods. *Marine Biology*, **144** (2), 225-230.
- Norderhaug, K.M., Christie, H. & Fredriksen, S. (2007). Is habitat size an important factor for faunal abundances on kelp (*Laminaria hyperborea*)? *Journal of Sea Research*, **58** (2), 120-124.
- Norderhaug, K.M. & Christie, H. (2011). Secondary production in a *Laminaria hyperborea* kelp forest and variation according to wave exposure. *Estuarine, Coastal and Shelf Science*, **95**(1), pp.135-144.
- O'Connor, M.I., Bruno, J.F., Gaines, S.D., Halpern, B.S., Lester, S.E., Kinlan, B.P. and Weiss, J.M. (2007). Temperature control of larval dispersal and the implications for marine ecology, evolution, and conservation. *Proceedings of the National Academy of Sciences*, **104**(4), pp.1266-1271.
- Picton, B.E. & Morrow C.C. (2005). *Encyclopedia of Marine Life of Britain and Ireland*
<http://www.habitas.org.uk/marinelife/species.asp?item=D10920>, 2008-01-08
- Rinkevich, B. (1996). Do reproduction and regeneration in damaged corals compete for energy allocation? *Mar Ecol Prog Ser* **143**:297–302
- Sainsbury, K.J., Campbell, R.A., Lindholm, R., Whitelaw, A.W. (1997). Experimental management of an Australian multispecies fishery: examining the possibility of trawl-induced habitat modification. In: Pikitch EK, Huppert DD, Sissenwine MP (eds) *Global trends: fisheries management*. American Fisheries Society, Bethesda, MD
- Sheehan, E.V., Stevens, T.F., Gall, S.C., Cousens, S.L. & Attrill, M.J. (2013). Recovery of a temperate reef assemblage in a marine protected area following the exclusion of towed demersal fishing. *Plos One*, **8** (12), e83883.
- Silén, L. (1981). Colony structure in *Flustra foliacea* (Linnaeus) (Bryozoa, Cheilostomata). *Acta Zoologica (Stockholm.)*, **62**, 219-232.

- Sjøtun, K., Christie, H. & Helge Fosså, J. (2006). The combined effect of canopy shading and sea urchin grazing on recruitment in kelp forest (*Laminaria hyperborea*). *Marine Biology Research*, **2** (1), 24-32.
- Smale, D.A., Burrows, M.T., Moore, P., O'Connor, N. & Hawkins, S.J. (2013). Threats and knowledge gaps for ecosystem services provided by kelp forests: a northeast Atlantic perspective. *Ecology and evolution*, **3** (11), 4016-4038.
- Stamp, T.E. (2015). *Alcyonium digitatum* with dense *Tubularia indivisa* and anemones on strongly tide-swept circalittoral rock. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: <http://www.marlin.ac.uk/habitat/detail/1053>
- Stamp, T.E. & Marshall, C.E. (2015). *Laminaria digitata*, ascidians and bryozoans on tide-swept sublittoral fringe rock. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: <http://www.marlin.ac.uk/habitat/detail/273>
- Stebbing, A.R.D. (1971). Growth of *Flustra foliacea* (Bryozoa). *Marine Biology*, **9**, 267-273.
- Tilmant, J.T. (1979). Observations on the impact of shrimp roller frame trawls operated over hard-bottom communities, Biscayne Bay, Florida: *National Park Service*.
- Tinsley, P. (2006). Worbarrow Reefs Sea Fan Project, 2003-2005 *Dorset Wildlife Trust Report*
- Tyler-Walters, H. (2005). *Bugula turbinata* An erect bryozoan. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available from: <http://www.marlin.ac.uk/species/detail/1715>
- Van Dolah, R.F., Wendt, P.H. & Nicholson, N. (1987). Effects of a research trawl on a hard-bottom assemblage of sponges and corals. *Fisheries Research*, **5** (1), 39-54.
- Vause, B.J., Beukers-Stewart, B.D. & Brand, A.R. (2007). Fluctuations and forecasts on the fishery for queen scallops (*Aequipecten opercularis*) around the isle of man. *Ices Journal of Marine Science* **64**: 1124-1135.
- Wassenberg, T.J., Dews, G., Cook, S.D. (2002). The impact of fish trawls on megabenthos (sponges) on the north-west shelf of Australia. *Fish Res* 58:141–151
- Weinberg, S. & Weinberg, F. (1979). The life cycle of a gorgonian: *Eunicella singularis* (Esper, 1794). *Bijdragen tot de Dierkunde*, **48** (2), 127-137.
- Whomersley, P. & Picken, G. (2003). Long-term dynamics of fouling communities found on offshore installations in the North Sea. *Journal of the Marine Biological Association of the UK*, **83** (5), 897-901.
- Wood, C. (2005). *Seasearch guide to sea anemones and corals of Britain and Ireland*. Ross-on-Wye: Marine Conservation Society.
- Wulff, J. (2006). Resistance vs recovery: morphological strategies of coral reef sponges. *Functional Ecology*, **20** (4), 699-708.
- Zintzen, V., Norro, A., Massin, C. & Mallefet, J. (2008). Temporal variation of *Tubularia indivisa* (Cnidaria, Tubulariidae) and associated epizoots on artificial habitat communities in the North Sea. *Marine Biology*, **153** (3), 405-420.

Annex 1

Data manipulation

'Bedrock reef' has been split apart from 'boulder and cobble' reef for the purposes of the Assessing Welsh Fishing Activities project so it aligns with the approach taken by Natural England for a related piece of work. This is the first time that this has been attempted for Welsh data.

The first stage of this process is to ascertain whether the habitat / data point is classified as 'reef'. For a habitat to be 'stony reef' it requires 10% or more of the seabed substratum at that location to be particles greater than 64mm across (i.e. cobbles). The figure of 10% is taken from a report determining the characteristics of stony reef (Irving, 2009). The remaining supporting 'matrix' could be of smaller sized material. The reef may be consistent in its coverage or it may form patches with intervening areas of finer sediment.

Bedrock reef, for the purposes of this exercise, is substratum which meets two conditions:

1. There is over 10% hard substratum in a finer sediment matrix, as described above.
2. The *proportion* of bedrock (of the total % rock in that location) is recorded as $\geq 50\%$ bedrock. (We acknowledge this means that the substratum could comprise of up to 49% cobbles and boulders and this would still class as subtidal bedrock reef, but the line has to be drawn somewhere if we are to split these reef types.)

As the habitat type is specified as *subtidal* reef, only those biotopes which are subtidal have been included in the definition of Subtidal Bedrock reef. Those points which contain Littoral Rock or Littoral Sediment biotopes have been omitted.

Annex 2

Biotopes that have been associated with the Subtidal bedrock reef habitat and their sensitivity to abrasion (MarLIN) (version 15.03) (JNCC - <http://jncc.defra.gov.uk/marine/biotopes/hierarchy.aspx?level=5>)

CR.FCR.Cv	High	CR.MCR.EcCr.FaAlCr.Car	Low	IR.HIR.KSed.XKScrR	Medium
CR.HCR.FaT.BalTub	Low	CR.MCR.EcCr.FaAlCr.Flu	Low	IR.LIR.IFaVS.MytRS	Medium
CR.HCR.FaT.CTub.Adig	Low	CR.MCR.EcCr.FaAlCr.Pom	Low	IR.LIR.K.LhypLsac	Medium
CR.HCR.XFa.ByErSp	Medium	CR.MCR.EcCr.FaAlCr.Sec	Low	IR.LIR.K.LhypLsac.Pk	Medium
CR.HCR.XFa.ByErSp.DysAct	Medium	CR.MCR.EcCr.UrtScr	Low	IR.LIR.K.Lsac.Ldig	Low
CR.HCR.XFa.ByErSp.Eun	Medium	CR.MCR.SfR.Hia	Medium	IR.LIR.K.Lsac.Pk	Low
CR.HCR.XFa.ByErSp.Sag	Medium	CR.MCR.SfR.Pol	Medium	IR.MIR.KR.HiaSw	Medium
CR.HCR.XFa.CvirCri	Low	IR.FIR.SG.CC	Low	IR.MIR.KR.Ldig.Bo	Medium
CR.HCR.XFa.FluCoAs	Low	IR.FIR.SG.CrSp	Low	IR.MIR.KR.Ldig.Ldig	Low
CR.HCR.XFa.FluCoAs.SmAs	Low	IR.FIR.SG.CrSpAsAn	Low	IR.MIR.KR.Ldig.Pid	Medium
CR.HCR.XFa.FluCoAs.X	Low	IR.FIR.SG.CrSpAsDenB	Low	IR.MIR.KR.Lhyp	Medium
CR.HCR.XFa.FluHocu	Low	IR.FIR.SG.DenCcor	Low	IR.MIR.KR.Lhyp.Ft	Medium
CR.HCR.XFa.Mol	Low	IR.FIR.SG.FoSwCC	Low	IR.MIR.KR.Lhyp.GzFt	Medium
CR.HCR.XFa.SpAnVt	Medium	IR.HIR.KFaR.Ala	Low	IR.MIR.KR.Lhyp.GzPk	Medium
CR.HCR.XFa.SpNemAdia	Medium	IR.HIR.KFaR.Ala.Ldig	Low	IR.MIR.KR.Lhyp.Pk	Medium
CR.HCR.XFa.SubCriTf	Medium	IR.HIR.KFaR.Ala.Myt	Low	IR.MIR.KR.LhypT	Medium
CR.MCR.CFaVS	Medium	IR.HIR.KFaR.FoR	Low	IR.MIR.KR.LhypT.Ft	Medium
CR.MCR.CFaVS.CuSpH	Medium	IR.HIR.KFaR.LhypFa	Medium	IR.MIR.KR.LhypT.Pk	Medium
CR.MCR.CMus.CMyt	Medium	IR.HIR.KFaR.LhypR	Medium	IR.MIR.KR.LhypTX.Ft	Medium
CR.MCR.CMus.Mdis	Medium	IR.HIR.KFaR.LhypR.Ft	Medium	IR.MIR.KR.LhypTX.Pk	Medium
CR.MCR.CSab	Medium	IR.HIR.KFaR.LhypR.Pk	Medium	IR.MIR.KR.LhypVt	Medium
CR.MCR.EcCr.AdigVt	Low	IR.HIR.KFaR.LhypRVt	Medium	IR.MIR.KR.XFoR	Low
CR.MCR.EcCr.CarSp	Low	IR.HIR.KSed.DesFilR	Medium	IR.MIR.KT.FilRVS	Low
CR.MCR.EcCr.CarSp.Bri	Medium	IR.HIR.KSed.LsacSac	Medium	IR.MIR.KT.LdigT	Medium
CR.MCR.EcCr.CarSp.PenPcom	Low	IR.HIR.KSed.ProtAhn	Low	IR.MIR.KT.LsacT	Medium
CR.MCR.EcCr.FaAlCr	Low	IR.HIR.KSed.Sac	Medium	IR.MIR.KT.XKT	Medium
CR.MCR.EcCr.FaAlCr.Bri	Medium	IR.HIR.KSed.XKHal	Medium		

