6.0 INTERTIDAL AND UNDERWATER FLORA & FAUNA, FISHERIES AND MARINE MAMMALS

This chapter provides an assessment of the likely impact on the marine ecological environment by the proposed gas storage facilities and associated construction work in Islandmagee, Co. Antrim. The assessment focuses on ecological features of conservation significance and specific methodologies used for the individual sub-sections of this Chapter are provided below.

6.1 INTRODUCTION

The principal focus of the impact assessment will be to consider the effects of a brine discharge on the marine habitats and communities. The brine outfall will discharge into the Irish Sea some 450m off the east coast of Islandmagee in approximately 27 metres water depth. A programme of marine ecological surveys was drawn up, centred on the eastern side of Islandmagee and focussed around the discharge area, with additional survey effort within Larne Lough on the western shores of Islandmagee, associated with aspects of the onshore gas storage facilities. Survey areas for the marine mammals and fisheries impact assessments extended further north and south along the coast, with both surveys also covering The Maidens.

Fieldwork for the intertidal and benthic impact assessment was undertaken in October and November 2009 and January 2010. Field surveys for the marine mammals impact assessment were undertaken on five occasions between September 2008 and September 2009. The pot fishery and bycatch information has been recorded on a monthly basis since December 2009.

6.1.1 Survey Extent and Rationale

6.1.1.1 Benthic Surveys

The 450m brine discharge pipe is proposed to be installed under the seabed using a microtunnelling method from land, so that the construction-phase impacts can be minimised. The diffuser outlet for at the end of this discharge pipe will be in 27m of water in an area of strong tidal currents, which will rapidly disperse the plume. A preliminary dispersion model prepared by RPS in September 2009 predicted the zone of mixing and dispersion of the brine discharge and this was used as a guide in setting the boundary of the benthic baseline sampling effort. Furthermore, the bathymetry of the eastern Islandmagee coast, in combination with local knowledge of the marine habitats in the area acquired during consultations with local fishermen and divers were also influential in determining a sampling plan. The coastline within the proposed discharge area is more or less straight, running roughly north west to south east between Portmuck (to the south) and Skernaghan Point. It then falls away fairly uniformly but steeply seaward with depth contours roughly parallel to the coast. Beyond the 20m contour the rate of decline in depth begins to slow and a wide mixed sediment plain is reached.

The preliminary model output indicated that the brine plume was likely to remain closer to the bottom than the surface and that its higher-concentration centre would be confined to a fairly limited near-field area around the 27m contour outlet point. Nevertheless, it was concluded at an early stage to widen the area of investigation well beyond this near-field area to cover all the main biotopes along this part of the coast and also to include areas close to Skernaghan Point, where local diving knowledge indicated that particularly diverse marine communities existed. Local knowledge also indicated that in the nearshore area as far as the 20m contour roughly, the bottom comprised rock, cobble and generally hard, broken ground, while beyond this point gravel-type substrates predominated. The former would be expected to have a predominant surface-associated community, most amenable to diver observation and video survey, whereas, the gravelly sediment would best be sampled using some form of dredge or other remote method.

Accordingly, the sampling area was laid out in a series of 9 parallel transect lines running at right angles out from the shore, the centre one running along the path of the brine outfall pipe and with the remaining transects placed 4 at either side at increasing spacing with distance from this central one. Along each transect line, putative sampling/observation points were placed so that they were concentrated in greater numbers along the central transects where the model predicted highest salinity concentrations, followed by fewer points on the transects farthest from the centre. The points were also chosen keeping depth in mind such that at least some sites in all transects could be compared with sites on other transects taken at the same depth. Two additional subtidal sampling points were chosen within Larne Lough, both located just off-shore from the proposed Gas Storage Plant facilities (see Figure). Beyond these observation points, in deeper water over coarse sediment, additional sampling sites were chosen for infaunal sampling using an anchor dredge.

6.1.1.2 Intertidal Surveys

In addition to these subtidal survey points, several intertidal transects were chosen both on the eastern and western shores of Islandmagee close in each case to where onshore or intertidal construction activity is proposed. Figures 6.3 and xx show the positions of all of the survey points chosen.

6.1.1.3 Marine Mammal Surveys

The survey area for the marine mammal field studies was identified by desktop assessment of known seal haul out areas and cetacean feeding areas. Further information on known local seal and cetacean feeding areas was also obtained by consultation with local fishermen and boat operators. The survey area covers Larne Lough, the eastern coast of Islandmagee including Muck Island and extends out to The Maidens.

6.1.1.4 Pot Fishery Surveys

The survey area for the pot fishery recording was determined by consultation with the local pot fishermen and by the Agri-Food and Biosciences Institute's knowledge of fishery operations within the vicinity of the proposed Islandmagee Storage Project. The survey area extends from Ballygalley in the north, to Cloghfin in the south, and incorporates The Maidens

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6.1.2 Survey Components

The benthic marine survey work comprised 4 separate components as follows:

- i) Intertidal survey
- ii) Drop-down Video Survey
- iii) Diver survey
- iv) Sediment Infaunal Sampling

6.1.2.1 Intertidal Survey

A standard intertidal transect survey with an additional overview survey of shore habitats was undertaken at 4 transects on the Larne Lough side and 4 on the eastern (outer) side of Islandmagee close to where on-shore facilities will operate.

6.1.2.2 Drop Down Video Survey

A drop-down video survey was undertaken in order to confirm the local knowledge of the site and to determine the nature of the bottom substrates throughout the study area and to present a preliminary overview of the biotopes (including floral and faunal elements). The video survey would also feed into the other sub-tidal survey components, in particular the diver survey.

6.1.2.3 Diver Survey

From the outset, a diver survey was considered essential, given the reportedly diverse hard-bottom communities known from the area. The dive survey concentrated on a selection of transects outlined in the sampling strategy and rationale above. The survey also included a number of 'spot-dives' in deeper water around the proposed outfall and in shallower water in Larne Lough.

6.1.2.4 Sediment Infaunal Survey.

3 grab samples and 10 anchor dredge samples were taken, mainly in the deeper water off the outer shore of Islandmagee. Anchor dredge was used where the video survey indicated that the sediment mainly comprised gravels, as a standard Day or Van Veen grab wouldn't be suitable due to the coarse nature of the sediment. Van Veen grab samples (0.1m²) were taken in one sandy (eastern side of Islandmagee) and two muddy sand areas (Larne Lough side), where the substrates were fine enough for grab penetration.

6.1.3 Survey Outputs

The findings of each of the four survey components is presented in the following sections:

Intertidal survey – Section 6.2
Drop-down Video Survey - Section 6.3
Diver survey - Section 6.4
Sediment Infaunal Sampling – Section 6.5

The predicted impacts to the marine habitats outlined within the above sections are examined in Section 6.6. The predicted impact to fisheries is examined in Section 6.7 and Marine Mammals are reviewed in Section 6.8.

6.2 INTERTIDAL FIELD SURVEYS

The eastern shore of Islandmagee faces Scotland and is open to the North Channel of the Irish Sea, while the western shore forms part of the eastern side of Larne Lough. The eastern side is exposed and comprises basalt bedrock, while the Larne Lough side is sheltered with a substrate comprising various proportions of gravel, pebbles cobbles and boulders. The eastern shores are short and steep, dropping off sharply at low water into deeper water, whereas, the Larne Lough side has slightly longer, gently sloping shores.

6.2.1 Methodology

6.2.1.1 Littoral Survey

On the eastern exposed shore, four transects were chosen; two at either side of the proposed seawater intake point (T1 and T2) and two just further south at either side of the proposed outfall pipeline route (T3 and T4). On the Larne Lough side, four transects were also chosen, two at either side of the Wellpad location (T5 and T6) and two about 1.5 kilometres further north west along the shore below the main gas plant facilities and associated vent stack, close to Ballylumford power station (T7 and T8) (see Figure 6.1 and Figure 6.2 for transect positions). The general nature of the shoreline and associated habitats and biotopes around and between these transects was also described. Fieldwork was undertaken on November 14th and 15th 2009 during spring tides. The eastern shore was accessed from the SNIP landfall area at Castle Robin Bay and the Larne Lough side by the proposed site access lanes. Due to steep rocky nature of the eastern shore backed by fairly high cliffs, it was difficult to get an overview of the shore much beyond the area encompassing the transects. Nevertheless, observations made from sea during the dropdown video survey along that shore would suggest that most of the shore line from Skernaghan Point south south east to Muck Island is very similar in broad structure. On the Larne Lough shore, while there are very few access point from the landward side, once on the shore it is relatively easy to traverse and the shore between transects was walked and described.

The biotopes encountered on along both shores was classified following the JNCC system (Connor et al., 2004), with a more detailed quadrat (0.25m²) survey at the 8 chosen transect sites. Abundance categories follow the SACFOR system of Hiscock (1996). Photographs of general features and individual quadrats were taken and positions were noted using a handheld Garmin-12 GPS (Table 6.1).

Figure 6.1 Intertidal transects, Islandmagee eastern shore

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Figure 6.2 Intertidal transects, Islandmagee western shore

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Table 6.1 Irish Grid Positions for 8 intertidal transects at Islandmagee

Shore	Transect Code	Easting	Northing
	T1	344600	403241
Footory share of lalandmages	T2	344667	403240
Eastern shore of Islandmagee	T3	344831	403158
	T4	344879	403119
	T5	343251	400769
Large Lavak above	T6	343219	400843
Larne Lough shore	T7	342694	401435
	T8	342539	401498

6.2.2 Results

Islandmagee – the Eastern Shore (Transects 1-4)

This is an exposed rocky shore running west north west – east south east from Skernaghan Point to Port Muck. The base rock is igneous volcanic in origin and very hard. The shores are short and steep and comprising massive rock outcrops fractured to form large moulded block –like structures (Plate 6.1& Plate 6.2). The shore is very sparse in terms of intertidal plants or animals between the upper (supra-littoral) lichen zones and the very upper part of the sub-tidal (infralittoral fringe). In general, macroalgal cover especially of brown seaweeds is confined to small isolated patches often of stunted plants in slightly more sheltered microhabitats. Locally very dense patches of the green alga *Cladophora rupestris* is a feature of the mid to upper shore in places, and appeared to be associated with fissures in the rock from which freshwater seepage may have emanated (Plate 6.3). A loose covering of *Enteromorpha* was also present in places.

The very upper zone on the shore (Supra littoral) was dominated by a yellow and grey lichens including Xanthoria, Lecanora atra, Caloplaca and stunted Ramalina, although the cover was not dense anywhere (Biotope: LR.FLR.Lic.YG - Yellow and grey lichens on supralittoral rock). Below this and often merging with it was an extensive zone of the black lichen Verrucaria maura, where the tiny gastropod snail Melarhaphe neritoides was locally abundant especially where the rock was minutely pitted and fissured (Biotope: LR.FLR.Lic.Ver.Ver - Verrucaria maura on very exposed to very sheltered upper littoral fringe rock). Very occasional patches of *Pelvetia* were also present but nowhere forming a zone. Between this and the very lower shore, there was no pronounced zonation, just generally bare rock with what appears to have been a diffuse cover of Verrucaria maura (not easily distinguished from the rock in places) with scattered limpets (Patella vulgata) and higher up small patches of Lichina sp. (Plate 6.4). Barnacles, mainly Semibalanus balanoides were very scarce except toward the extreme lower shore where they became more abundant (Plate 6.5). Within the mid to low shore this generally bare rock substrate was interspersed with a localised low density of seaweed patches (e.g. stunted Ascophyllum - mainly without bladders), patches of Cladophora rupestris and small shallow rock pools coated in encrusting calcareous red algae or Corallina sp. (Biotope: LR.FLR.Rkp.Cor.Cor:Coralline crusts and Corallina officinalis in shallow eulittoral rockpools) (Plate 6.6 & Plate 6.7). At the very lowest part of the shore just above the Kelp zone, on sloping wave-swept rock, encrusting coralline algae, Corallina and low turfs of seaweed (mainly Osmundea pinnatifida) formed a narrow loose zone (Biotope: LR.HLR.FR.Coff.Coff Corallina officinalis and Mastocarpus stellatus on exposed to moderately exposed lower eulittoral rock) (Plate 6.8).

Larne Lough Shore (Transects 5 – 8).

The Larne Lough shore under consideration is on the eastern side of the Lough and runs from Ballylumford Power Station south for roughly 1.5 kilometres. The area is virtually fully marine in terns of salinity and is sheltered to very sheltered in terms of exposure. Tidal currents, at least within the study area, appear to be very slack. These features, combined with the intertidal substrate define the character of its biotopes. In broad terms this shore can be defined as a sheltered mixed hard substrate shore. These conditions allow brown macro-algae to flourish but not in the luxuriant abundances that a purely rock substrate might in such conditions (Plate 6.9). The principle substrates are small cobbles, pebbles and gravel with scattered small boulders, while a short stretch of shore (100-200m) is dominated by a boulder field (Plate 6.10) and a small low rock intrusion (weathered chert / flint - in the mid tidal toward the Ballylumford end of the study area –was also noted (Plate 6.11)

The Yellow-Grey lichen biotope (LR.FLR.Lic.YG) characteristic of stable hard substrates is virtually absent from all four transects and only notable by the boulder field referred above. Below this a well - defined Pelvetia zone (Biotope: LR.LLR.F.Pel - Pelvetia canaliculata on sheltered littoral fringe rock) is also generally absent, even though there are patches of localised luxuriant growth (Plate 6.12). A distinct Fucus spiralis zone biotope (LR.LLR.F.Fspi.X - Fucus spiralis on full salinity upper eulittoral mixed substrata), isn't easily discernible as it merges into Fucus vesiculosus zone (Biotope: LR.LLR.F.Fves.X - Fucus vesiculosus on mid eulittoral mixed substrata) and because there are no fruiting bodies or bladders on much of the material it is difficult to say exactly which species one is dealing with until paired bladders appear distinctly on F. vesiculosus further down the transects. Fucus vesiculosus zone is the most distinctive. A defined Fucus serratus biotope wasn't discernible during low spring tide of the survey. However, a lower spring tide might reveal one. Diver and video survey of the shallow sub-tidal in the area noted the extensive presence of a soft sediment bottom, probably either muddy sand or sandy mud. Red algae were virtually absent in the intertidal and ephemeral greens, perhaps because of the late season, were also fairly scarce.

In terms of fauna, *Littorina saxatilis* was prominent in the upper shore especially where one would expect a *Pelvetia* zone to be present and also among the *Fucus spiralis* and also, commonly, in areas devoid of macroalgal cover where small cobbles and boulders was the dominant substrate (Plate 6.13). Barnacles, mainly *Semibalanus balanoides* were scarce on the shore but became more numerous in certain areas with boulders and more generally toward the mid to lower half of the shore. The winkles, *Littorina litorea* were frequently encountered along with *L. obtusata/mariae*, the latter especially associated with brown seaweed. *Littorina litorea* were being harvested in the area of Transect 6 on the day of the survey. Limpets, *Patella vulgata* were frequently encountered in the mid to lower shore, while top shells, mainly *Gibbula umbilicalis* were occasionally to frequently found in the lower

parts of transects. Amphipods were locally common throughout, mainly under stones while small specimens of ¹shore crabs (*Carcinus maenas*) were frequently encountered under and between stones, especially with in areas with algal cover.

In general, all the flora and fauna encountered would be described as typical of mixed hard substrate full salinity, sheltered shores. See Appendix 6.1 for details of individual transects. Appendix 6.2 presents detailed descriptions of the Biotope categories which characterised both shores.

6.2.2.1 Plates - Eastern Shore



Plate 6.1 Eastern shore showing fissured blocks of bedrock

¹ Also know as green crabs



Plate 6.2 Eastern shore from higher vantage (view to SSE)

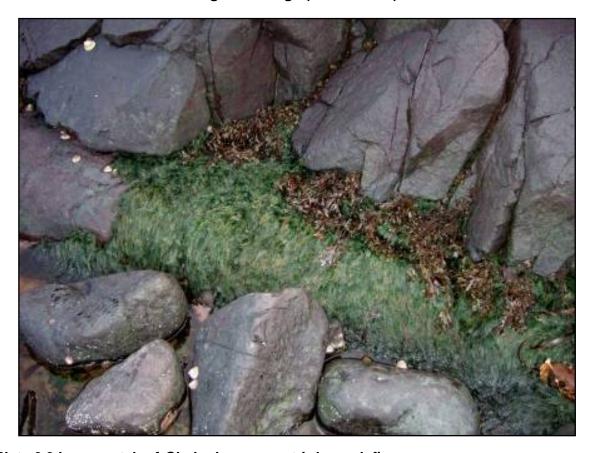


Plate 6.3 Large patch of Cladophora rupestris by rock fissure



Plate 6.4 Patch of *Lichina* over *Verrucaria*, with *Melarhaph*e and *Littorina* in pits and fissures in the rock.



Plate 6.5 Barnacles on rock at extreme lower shore at low water.



Plate 6.6 Shallow rock pool with encrusting calcareous red alga and limpets.



Plate 6.7 Small lower shore rock pool with encrusting calcareous red alga, *Corallina* and *Fucus serratus*



Plate 6.8 Narrow loose zone of *Corallina* and red algal turfs at extreme low tide. Note kelp (*Laminaria digitata*) in background).

6.2.3 Plates - Larne Lough Shore



Plate 6.9 *Fucus* seaweed on mixed sediment – mid shore (near Transect 6 – view to the south).

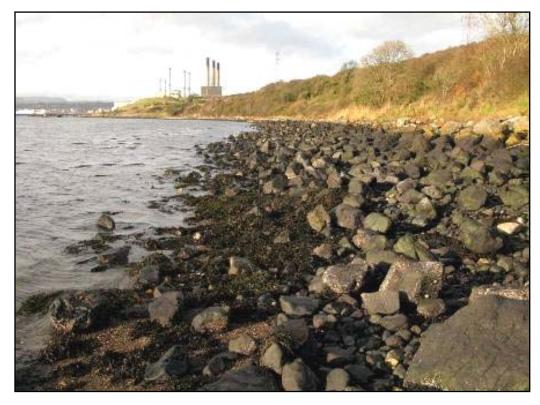


Plate 6.10 Stretch of boulders between Transect 6 and 7 (view north to Ballylumford power station).

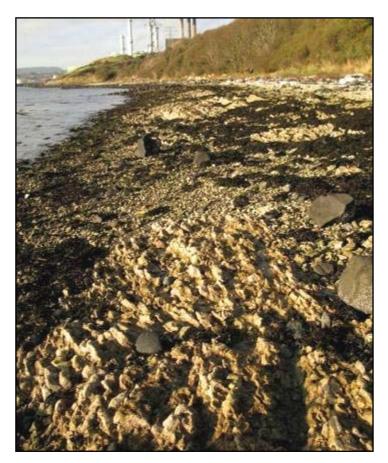


Plate 6.11 Short stretch of exposed bedrock (baked limestone) between Transect 6 and 7



Plate 6.12 Littorina saxatilis on small bare cobbles in the upper shore.

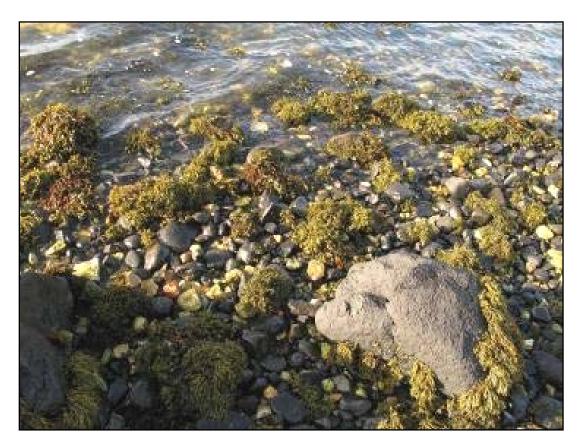


Plate 6.13 *Pelvetia* on small cobbles and boulders on the upper shore (between T5 and T6)

6.3 BENTHIC VIDEO BASELINE SURVEY

A ROV video survey was undertaken during neap tide on 13th and 14th October 2009 at several stations across a 2km section of coastline on the eastern (centred around the proposed outfall route, see Figure 6.4) and western shores (centred on the main gas plant and wellpad - Figure 6.5) of Islandmagee to establish broad biotope types and identify potentially sensitive habitats.

The video survey was carried using an Outland drop-camera system. This system is powered by a LED light source and normally diver operated but is also modifiable for remote deployment, which is how it was operated in this case.

6.3.1 Methods

The video camera and LED light were attached to a small cage designed to keep the camera off the bottom and within the minimum fixed focal distance. The whole unit was connected by cable and tether line to the boat (North Island Diver) where it fed into a video capture control box and linked laptop computer. At each site the video was dropped and recordings made for a few minutes while the boat drifted. Every effort was made to deploy only at slack water in order to minimise camera movement but this wasn't always achievable. In most cases, the cage dropped to the bottom allowed at least some 'still' footage to be captured at all sites, but at some it is quite limited due to the strength of the bottom currents. Nevertheless, the principle substrate type and associated broad community components can be discerned in all cases.

6.3.2 Points Surveyed

35 drop-down stations out of a possible 41 were sampled (Figure 6.4). Table 6.2 lists the positions in Irish Grid of each station surveyed.

Table 6.2 Video Survey Coordinates (Irish Grid)

Station	Depth (m)	Easting	Northing
1	23	343909.8	403922.5
2	17.5	343831.1	403807.7
3	12	343767.1	403690.4
4	25.6	344371.5	403730.7
5	13	344292.9	403615.8
6	6	344228.9	403498.5
7	23	344833.3	403538.8
8	13.7	344754.6	403424.0
9	6	344690.6	403306.7
10	30.7	345100.0	403639.7
13	22	344937.5	403405.4
14	11.7	344883.3	403327.3

Station	Depth (m)	Easting	Northing
22	14.6	344937.7	403273.7
23	7.5	344894.5	403212.4
24	3.6	344866.5	403172.8
27	25	345099.5	403360.6
28	23	345061.8	403317.7
29	17	345006.4	403240.4
30	6.7	344951.1	403163.2
31	26	345225.6	403268.9
32	17	345127.8	403162.2
33	7.3	345072.4	403075.0
34	20.2	345630.1	402974.9
35	14.4	345532.2	402868.3

Station	Depth (m)	Easting	Northing
15	8.5	344829.1	403249.1
16	31	345197.0	403641.5
17	31	345153.8	403580.2
19	27	345067.4	403457.6
21	19	344981.0	403335.0

Station	Depth (m)	Easting	Northing
36	7.7	345476.9	402781.0
37	14	346034.6	402681.0
38	8.5	345936.7	402574.3
39	4.5	345881.3	402487.1
40	6.7	342534.6	401359.9
41	4.1	343125.5	400751.4

6.3.3 Results

A brief description of each video drop clip is presented in Appendix 6.3 while selected frame grabs for each site are presented in Appendix 6.4.

6.3.4 Discussion

<u>6.3.4.1</u> Overview

By and large, as expected, the nature of the bottom substrates and associated biotic communities followed a fairly predictable depth-related pattern, whereby stations across different transects but on the same depth contours had very similar substrates and communities epibenthic communities.

6.3.4.2 Principal Station Groupings based on Video Observations

Video observations suggest 3 larger station groupings, which relate to a combination of substrate type and depth. In addition there are a number of smaller groupings related to substrate type and possibly water movements.

is a schematic of these stations as presented in indicating by colour the interrelationship between the stations as revealed using drop-down video. The sites are laid out to resemble their distribution in Figure 6.3 with the lower end of the figure representing the eastern shoreline of Islandmagee and Station 16, indicating the farthest offshore site. The two 'detached sites, Site 40 and 41 were the only two sampled within Larne Lough.

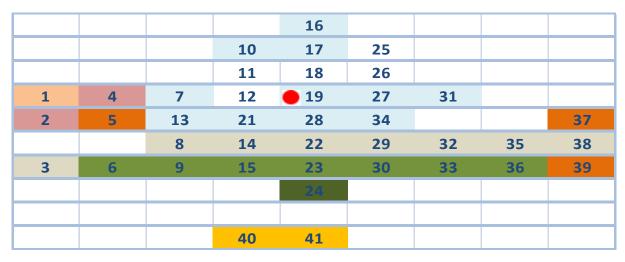


Figure 6.3 Schematic of video station layout and interrelations (by colour)

The following paragraphs outline the groupings referred to above and in and the nature of the habitats and dominant epibenthic communities occurring on each.

<u>Station Group 1</u> includes most of the stations between the 20 and 30m contours; these include stations dominated by gravel or sandy gravel: 16, 10, 17, 7, 19, 27, 31, 13, 21, 28, and 34. Station 1 also belongs loosely to this station grouping.

<u>Station Group 2</u> lie mainly between the 10 and 20m contour over mixed cobble, boulder, pebble, sand and gravel and comprise Stations: 8, 14, 22, 29, 32, 35 and 38.

<u>Station Group 3</u> straddles the 5m contour and includes Stations 6, 9, 15, 30, 33 and 36, which overly bedrock, cobble, boulder and pebble with highest densities of kelp.

<u>Station Group 3a</u> comprises just one station i.e. the shallow hard substrate 24, just shoreward of the related Group 3 stations.

<u>Station Group 4</u> comprises Stations 2 and 4 the former in 17.5 m and the latter in 25.6m, both of which share a dense population of brittle stars as well as a diverse range of bryozoan species.

<u>Station Group 5</u> includes Stations 40 and 41 both on the Larne Lough side of Islandmagee and both between 5 and 10m depth.

Other stations appear not to fit easily into any grouping. These include Stations 39, 37, 3 and 1

6.3.4.3 Station Group Descriptions

The following paragraphs draw together the main characteristics of the habitats noted in the drop-down video survey. An attempt has also been made to classify each into the JNCC biotope categories and their EUNIS equivalents, nevertheless, where these overlap with the diver survey and the infaunal dredge surveys, the classifications from these should take

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precedence. It should also be noted that often several habitats may intermingle in a kind of mosaic, whereas only the predominant may be described.

Group 1 Stations

These are notable for their gravel or shell gravel substrate with varying degrees of silt or fine sand cover and occasionally with scattered small cobbles. Generally, the sites are free of algae or have very scattered and small clumps of foliose reds. Brittle stars (different species) from those in Stations Group 5, are occasional to frequently encountered, while bryozoa, in particular Flustra and Alcyonidium are frequent or locally common. Other larger and easily identifiable fauna, which occur sporadically, include starfish (Solaster papposus, Asterias rubens and Henricia sp.?) and less often the urchin Echinus esculenta. Encrusting fauna e.g. barnacles (Balanus crenatus) and keelworms (Pomatoceros) are frequently visible on larger pebbles and shells. Within this group, the 3 deepest stations (16, 10 and 17) are distinguishable by the higher proportions of shell in the substrate and by a layer of fine sand or silt interspersed among the shell. Site 17 has more frequent bryozoa than the other two. The remaining eight stations are mainly gravel or sandy gravel, with Station 21 standing out in having a much higher proportion of sand. Stations also differ in the frequency of occurrence of brittle stars, encrusting organisms (barnacles), the diversity and cover of bryozoa (the latter which is, however, generally low throughout) and the frequency of occurrence of red algae (also generally very low). Site 19 has a greater frequency of scattered small cobbles, while Site 7 has a generally higher representation of bryozoa. Small shoals of fish occur sporadically throughout. Site 1 could be loosely associated with this station grouping as it is dominated by sandy gravel substrate. However, it has a generally, higher diversity and density of attached epibenthic species mainly bryozoans (and hydroids ?). These sites all fall into the broad JNCC classification Circalittoral Sediments, in subclassifications of Circalittoral Coarse Sediment (SS.SCS.CCS) (EUNIS A5.14) or Circalittoral Mixed Sediment (SS.SMx.CMx) (EUNIS A5.44).

Group 2 Stations

These stations are characterised by a combination of large cobbles, boulders and broken bedrock with occasionally large patches of fine or medium sand with scattered patches of gravel. Foliose red algae are widespread and locally common, while kelp is present but generally at very low densities. Cup corals or small anemones are common on large boulders, as are sponge patches and patches of encrusting calcareous red algae. Station 32 is exceptional is having a very high cover of sand. In general, in extensive sandy areas, small, low scattered cobbles are often colonised by a mix of the bryozoans and red algae, which suggests high sand scour in theses areas. Station 38 appears to have a more frequent cover of kelp (*L. hyperborea*). The sea urchin *Echinus esculentus* was recorded at several stations (most in 38), while burrowing anemones were noted in sandy areas. These stations are not easily classifiable within the JNCC Biotope hierarchy, but falling somewhere between lower Infralittoral and upper Circalittoral in terms of depth. Possibly best in CR.MCR (Moderate energy circalittoral rock) (EUNIS A4.2) and within this the broad sub-classification: Echinoderms and crustose communities (CR.MCR.EcCr) (EUNIS A4.21).

Group 3 Stations

The stations were characterised by bedrock, boulders and large pebble and gravel patches with a denser and occasionally luxuriant cover of red algae on bedrock and epiphytically on Laminaria hyperborea stipes. Boulders often had large patches of encrusting calcareous red algae but seemingly few cup-corals and sponge patches. Kelp was generally more frequent than in Group 2 stations and dominated by L. hyperborea. Desmarestia aculeata was another frequently occurring brown algae, while reds Delesseria sanguinea, Odonthalia dentata, Dilsea carnosa and Callophyllis laciniata are all well represented, with the first and second species quite prominent. These stations could fit the JNCC Classification: Laminaria hyperborea with dense foliose red seaweeds on exposed infralittoral IR.HIR.KFaR.LhypR (Eunis A3.115) or could also be classified as Sediment-affected or disturbed kelp and seaweed communities IR.HIR.Ksed (Eunis A3.12) because of the sandy cover noted on rock in some areas.

Group 3a Stations

Station 24, the shallowest and most nearshore station surveyed was the only one in this group. It was distinguishable by having a dense *Laminaria hyperborea* forest with frequent occurrences of *Saccorhiza polyschides* and localised concentrations of *Saccharina latissima* also. *Laminaria digitata* was not observed with certainty but may well also be present in this area. The understorey was generally quite sparse of red algae compared to concentrations observed at Group 3 sites, although red epiphytic growth on kelp stipes was luxuriant, especially of *Palmaria palmata*, and kelp sporlings were frequently observed on some small boulders. This habitat is closest to the JNCC Classification: Laminaria hyperborea and foliose red seaweeds on moderately exposed infralittoral rock (IR.MIR.KR.Lhyp) (ENIS A3.214) but also has similarities with: Laminaria hyperborea forest with dense foliose red seaweeds on exposed upper infralittoral rock IR.HIR.KFaR.LhypR.Ft (EUNIS A3.1151) due to the presence of *Sacchoriza polyschides* and ²*Saccharina latissima*.

Group 4 Stations

This group comprises just 2 stations, both of which are notable for a high density of brittle stars, especially the former. The species in question include *Ophiocomina nigra*, a black species and *Ophiothrix fragilis* a species with strikingly banded arms. *O. nigra* is slightly more prominent in Station 2 while *O. fragilis* is more common at Station 4. Both stations also have a diverse range of bryozoans, especially at Site 2, where they are also denser. Both stations have a substrate of sandy gravel or gravely sand with a high proportion of large pebble with encrusting fauna. Large, solitary, worm tubes are frequently observed in the Station 2 video. Both these stations are closer to Skernaghan Point and may therefore be subject to stronger water currents, which would favour the feeding of the brittles stars. They can be broadly classified under the SS.SMx.CMx.OphMx (Ophiothrix fragilis and/or Ophiocomina nigra brittlestar beds on sublittoral mixed sediment) (EUNIS A5.445).

Group 5 Stations

This group also includes a pair of stations, the only ones within the sheltered waters of Larne Lough. Stations 40 and 41 both occur over muddy sand, with a fine shell fraction, in shallow

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² Formerly Laminaria saccharina

water. Both are typified by expanses of fairly bare substrate, although Station 41 had a much greater cover of red, green and brown seaweed (dense in places), including *S. latissima* and *Ulva*. Burrowing anemones are prominent at both stations and several crabs are visible in the footage from both stations (*Carcinus maenas*, *Liocarcinus* sp. and possibly *Cancer pagurus*). These sites, particularly the latter Station 41) may be part of the general JNCC biotope: Laminaria saccharina and red seaweeds on infralittoral sediments (SS.SMp.KSwSS.LsacR) (EUNIS A5.521). However, the sediment infauna may classify the site differently e.g. Infralittoral sandy mud. (S.SMu.IsaMu) (EUNIS A5.33).

Other Stations

Station 39 at Portmuck comprises clean, medium to coarse shallow-rippled sand, with occasional burrows visible. It fits closest to JNCC biotope Infralittoral Fine Sand (SS.SSa.IfiSa – Eunis A5.23)

Station 37, which is farther offshore than 39 also has a prominent expanse of fine to medium sand, with scattered patches of gravel/small stones colonised by red algae and bryozoans.

Station 3 comprises rounded boulders with small clumps of red algae and several sea urchins (*Echinus*), it could fit into Station Group 2, although shallower and with less sand.

Station 1 lies in 23 m off Skernaghan Point, is quite similar to Sites 2 and 4 but without the dense brittle star population, but also has elements in common with Group 1 stations. It has a gravel and small cobble/large pebble substrate with a dense epilithic growth of bryozoa (probably hydroids), encrusting worms and barnacles and scattered prominent tubes belonging to a filter-feeding polychaete species.

6.4 **DIVE SURVEY**

The following sections give a brief outline of the habitats identified on 12 dives carried on an area of seafloor NW of Portmuck, County Antrim, on 10th and 11th November 2009. A map is presented at the end of this report which shows expected habitat distribution on the site based on the results of these dives.

The report follows the following structure:

- Each site/transect is initially named and the type of dive carried out is described (level 2 headings of this report). Notes specific to the dive carried out are added.
- A broad classification of the site habitat types is then given e.g. Circalittoral mixed sediment (EUNIS hierarchy Level 4).
- For each of the broad habitat types identified, more detailed classifications are assigned Ophiothrix fragilis &/or Ophiocomina nigra brittlestar beds on where possible e.g. sublittoral mixed sediment (EUNIS hierarchy Level 5). A representative photograph for the identified habitat type is presented beneath its description.
- Photographs of species of interest are also presented.

An attempt was made to choose the best matching habitats based on depth, energy, community type and species composition. However, it should be noted that the species composition of the assigned habitats may not always completely define the community present. Variation in community species composition associated with a particular substrate type is not always accommodated in the EUNIS habitat classification. Habitats in transition zones are notoriously difficult to accurately classify using the existing system. Habitats tend to follow a continuum of change in species composition, as opposed to existing in discrete units. Where two habitats adjoin, the species composition of one habitat will often blend into that of another before becoming a distinctly different habitat. Where appropriate, notes to this effect are made in the text of the following summary of habitat types.

Due to the time of year at which the survey was carried out, many of the seasonal seaweeds were dying back for the winter. Future surveys carried out in this area should take this into account.

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Figure 6.4 Location of Dive Stations (East Coast)

Figure 6.5 Location of Dive Stations (West Coast)

6.4.1 Survey Methodology

The survey work was carried out by a team of experienced scientific divers from a 10.5m customised Rigid Inflatable Boat on 10th and 11th November 2009. The survey work included investigation of the seafloor on six individual stations and along six transects. A total of 12 dives were carried out. T

The stations surveyed were as follows and are shown in **Error! Reference source not found.**:

- 2, 17, 19, 250m NW of 19, 250m SE of 19. A dive was conducted on ROV Station 42, inside the Lough shown in Figure 6.5 inside the Lough,
- Transects were surveyed between stations 7-8, 8-9, 20-21, 22-23, 31-32, 32-22

he following method was employed during the subtidal survey work::

A: Individual Stations

After careful positioning of the survey vessel by the skipper a buoyed shot line was dropped on the exact station coordinates.

- Two divers equipped with standard SCUBA gear entered the water and descended from the buoy along the line to the shot weight.
- The seafloor was investigated to a radius of 20m around the location of the shot marker

B: Transects between Stations

- After careful positioning of the survey vessel by the skipper a buoyed shot line was
 dropped on the exact coordinates of the station at the deeper end of the transect.
- The divers took a compass bearing perpendicular to the coast that would lead them directly inshore to the inner station.
- Two divers equipped with standard SCUBA gear entered the water and descended from the buoy along the line to the shot weight.
- A transect was then swum between this point and the inner, shallower station. Notes
 of observations and photographs were taken at regular intervals over the course of
 the dive.

The divers were equipped with dive slates and waterproof pencils for note-taking, torches for illumination and a digital camera system. The camera used was a Nikon D200 with a 12mm to 24mm wide-angle lens inside a Subal ND20 housing fitted with dual Inon strobes. Floral and faunal abundance was estimated on a SACFOR scale (Superabundant, Abundant, Common, Frequent, Occasional, Rare). Notes and photographs were taken during the course of the dives. Specimens of some floral and faunal species were gathered for examination in the laboratory. A final species list was drawn up during discussion between the divers on return to the surface. The photographs were examined in detail following the

fieldwork and the species list updated, where necessary, to include any animals and plants that may have been missed during the dive work.

A 0.25m² quadrat was taken along on the dive. This was photographed on the various habitats encountered during the dives both for scaling purposes and to allow a more detailed quantification of species cover to be carried out if desired.

A complete species list along with abundances found at each station is included as Appendix 6.5. The species records for some of the transect dives have been split between two or more columns where distinct changes in substrate, depth or species composition were noted. A DVD containing all images taken during the survey is included as Appendix 6.11. Detailed EUNIS habitat descriptions are given in Appendix 6.6.

6.4.2 Summary table

The following table gives an overview of the habitats identified at each station. The general pattern of habitat distribution with depth was as follows:

33m-20m – mixed circalittoral sediments with bryozoan dominated epifaunal communities of variable species composition. Occasional boulders depending on site

20m-16m – mixed circalittoral sediments with boulder field, occasional rock outcrops. Community changing from bryozoan-dominated to bryozoan and foliose red weeds

16m-7m – boulder field and fissured bedrock with patches of mixed sediments. Community becoming increasingly algal-dominated (kelp) with decreasing depth.

The communities recorded during this work were generally sparse tide-swept/sediment disturbed communities. Full descriptions of the EUNIS habitat classifications referred to in this report are given in Appendix 6.6.

Table 6.3 Overview of the habitats identified during each dive

							Station/Transect	ransect					
EUNIS	Habitat	82	87-8	6-85	S17	S19	250m SE S19	250m NW S19	S20-21	S22-23	31-32	S32-33	S41
A3.11	Kelp with cushion									*		*	
	fauna &/or foliose reds												
A2 1152	L. hyperborea park with									*			
A3.1132	dense foliose reds												
9	Sediment-affected			,									
A3.12	kelp & seaweeds												
, c ,	Mixed kelps with scour		*							*		*	
A3.120	tolerant reds												
22.44	Encrusting algal	*											
A5. 14	communities												
70.72	Echinoderms/crustose			,		*						•	
A4.21	on circalittoral rock					ı							
24.04.4	C. smithii sponges &											•	
A4.212	crustose communities												
A4.214	Faunal/algal crusts	*											
A4.2141	Flustra, scoured rock			*									
A4.2145	Faunal/algal crusts		٠	*		*							
A5.2	Sublittoral sand												
76.40	Infralittoral mixed									*			
40.4	sediments												
A5.44	Circalittoral mixed	*		*	*	*	*	*	*		*	٠	
	sediments												
A5.444	Flustra/Hydrallmania	*	*	*		*		*	*		*	*	
A5.446	Sandy mixed sed with				*		*		*		*		
	Alcyonidium												
A 5, 445	Brittlestar beds on	*											
	sublittoral mixed seds												

6.4.3 DIVE 1 – Located at ROV Station 2 – (Depth 18m)

The following habitats were identified on Station 2:

- Circalittoral mixed sediments
 - o O. fragilis &/or O. nigra brittlestar beds on sublittoral mixed sediment
 - o F. foliacea & H. falcata on tide-swept circalittoral mixed sediment
- Echinoderms & crustose communities on circalittoral rock
 - Encrusting algal communities (crust) (proposed new unit)
 - Faunal/algal crusts on exposed/moderately wave-exposed rock

Brief seafloor description:

One dive was carried out at Station 2 at a depth of 18m. Both an ophiuroid-dominated and a bryozoan/hydroid turf community were present. Both were present on mixed circalittoral sediments – a stable seafloor with sand-embedded cobbles and occasional boulders. Much of the exposed surfaces of the cobbles and boulders were covered with encrusting coralline algae. The boulder habitat is considered separately.

6.4.3.1 DIVE 1/Station 2 - General classification (a) - Circalittoral mixed sediments - EUNIS A5.44

Mixed (heterogeneous) sediment habitats in the circalittoral zone (generally below 15-20 m) including well mixed muddy gravelly sands or very poorly sorted mosaics of shell, cobbles and pebbles embedded in or lying upon mud, sand or gravel. Due to the variable nature of the seabed a variety of communities can develop which are often very diverse. See Appendix 6.6 for full descriptions of the EUNIS habitat classifications referred to in this report.

<u>DIVE 1/Station 2: Habitat 1 – Ophiothrix fragilis &/or Ophiocomina nigra brittlestar beds on</u> sublittoral mixed sediment – EUNIS A5.445

Circalittoral sediment dominated by brittlestars (hundreds or thousands m²) forming dense beds, living epifaunally on boulder, gravel or sedimentary substrata. This is the habitat most closely describing dive site 2. However, this habitat is equally characterised by a bryozoan and hydroid-dominated community (*Cellaria sinuosa*, *Flustra foliacea*, *Eucratea loricata* and *Hydrallmania falcata*) – which does not quite fit the brittlestar beds classification.

<u>DIVE 1/Station 2: Habitat 2 – Flustra foliacea and Hydrallmania falcata on tide-swept circalittoral mixed sediment – EUNIS A5.444</u>

This biotope represents part of a transition between sand-scoured circalittoral rock where the epifauna is conspicuous enough to be considered as a biotope and a sediment biotope where an infaunal sample is required to characterise it and is possibly best considered an epibiotic overlay.



Plate 6.14 *Ophiothrix sp., Ophiocomina sp.* and bryozoans on mixed sublittoral sediment (Station 2, Habitat 1)



Plate 6.15 Flustra sp., mixed bryozoans and hydroids on tide swept circalittoral mixed sediment (Station 2, Habitat 2)

However, many species not stated in the species list given for this habitat in the EUNIS classification are present (notably bryozoans *Cellaria sinuosa* and *Eucratea loricata* and ophiuroids).

6.4.3.2 <u>DIVE 1/Station 2 General classification (b) – Echinoderms and crustose communities on</u> circalittoral rock - EUNIS A4.21

This habitat type occurs on wave-exposed, moderately strong to weakly tide-swept, circalittoral bedrock and boulders. Echinoderms, faunal *Parasmittina trispinosa* and algal crusts (red encrusting algae) dominate this biotope, giving a sparse appearance. Typical echinoderms present are the starfish *Asterias rubens*, the brittlestar *Ophiothrix fragilis* and the sea urchin *Echinus esculentus*. There may be isolated clumps of the hydroids *Nemertesia antennina* and *Abietinaria abietina*, *Alcyonium digitatum*, the anemone *Urticina felina* and the cup coral *Caryophyllia smithii*. Other species present may include the polychaete *Pomatoceros triqueter* and the top shell *Calliostoma zizphinum*.

DIVE1/Station 2: Habitat 3 – Encrusting algal communities (crust) – EUNIS A3.14 (proposed new unit) / Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock A4.214



Plate 6.16 Algal encrusted boulder with *Pomatoceros sp., Balanus* sp. and *Echinus* sp. (Station 2, Habitat 3).

This biotope typically occurs on the vertical and upper faces of wave-exposed and moderately wave-exposed circalittoral bedrock or boulders subject to mostly moderate to weak tidal streams (a variant of this biotope containing brittlestar is found on bedrock, boulders and cobbles). The biotope is dominated by faunal (e.g. *Parasmittina trispinosa* and algal (Corallinaceae) crusts, and tends to have a grazed appearance; this may be partially attributable to the abundance of *Echinus esculentus* found in this biotope. Occasionally, the rock may appear pink from a distance, due to the expanses of encrusting red algae on the rock surface.

Several boulders were encountered that were overwhelmingly dominated by algal crusts – these constitute a third habitat for Station 2. This habitat falls under EUNIS A3 (Infralittoral rock and other hard substrata). The specific sub-group of encrusting algal communities is a proposed unit only but perhaps best describes this particular habitat.

Plate 6.17, Plate 6.18, Plate 6.19 and Plate 6.20 show a selection of photographs of the species encountered at Station 2 during Dive 1.



Plate 6.17 Example of one of the photo quadrat photographs taken at Station 2.



Plate 6.18 Munida rugosa, Station 2



Plate 6.19 The curled octopus, *Eledone cirrhosa*, at rest, Station 2



Plate 6.20 Dahlia anemone (Urticina felina) and hornwrack (Flustra foliacea), Station 2.

6.4.4 DIVE 2 - Transect between ROV Stations 7 & 8 (T7-8) (Depth 26.2m - 17.2m)

The following habitats were identified on T7-8:

- Circalittoral mixed sediments
 - o F. foliacea & H. falcata on tide-swept circalittoral mixed sediment
- Echinoderms & crustose communities on circalittoral rock
 - Faunal and algal crusts with P. triqueter & sparse A. digitatum on exposed to moderately wave-exposed circalittoral rock
- Sediment-affected or disturbed kelp and seaweed communities
 - Mixed kelps with scour-tolerant and opportunistic foliose red seaweeds on scoured or sand-covered infralittoral rock

Brief seafloor description:

One dive transect was carried out between ROV Stations 7 and 8. Depths at the beginning and end of the transect were 26.2m and 17.2m, respectively. The seafloor here is quite patchy in nature – e.g. areas with dense stands of bryozoans and foliose red algae may adjoin areas with very sparse epifauna/flora.

The dive began on pebbly sandy gravel. Moving shoreward, boulders and large cobbles were recorded along with exposed low bedrock outcrops. The dive ended on bedrock and large boulders with a kelp community (*Laminaria hyperborea* based).

6.4.4.1 <u>Dive 2/Transect 7-8 General classification (a) – Circalittoral mixed sediments - EUNIS</u> A5.44

<u>DIVE 2/Transect 7-8: Habitat 1 – Flustra foliacea & Hydrallmania falcata on tide-swept circalittoral mixed sediment – EUNIS A5.444</u>

This was an animal-dominated community on circalittoral mixed circalittoral sediment (sand, shell,pebble and cobble with occasional boulders). The habitat category roughly fits the depth, community and substrate. However the species composition is quite different – less hydroid and more bryozoan-dominated (notable bryozoans *Cellaria sinuosa* and *Eucratea loricata* and ophiuroids). Tube-dwelling polychaetes also contribute notably to species composition.

6.4.4.2 <u>Dive 2/Transect 7-8 - General classification (b) - Echinoderms and crustose</u> communities on circalittoral rock - EUNIS A4.21

<u>DIVE 2/Transect 7-8: Habitat 2 – Faunal and algal crusts with *Pomatoceros triquete*r and sparse *Alcyonium digitatum* on exposed to moderately wave-exposed circalittoral rock – EUNIS A4.2145</u>

This variant is typically found on the upper faces of exposed and moderately exposed circalittoral bedrock or boulders subjected to moderately strong to weak tidal streams. Several boulders were encountered that were overwhelmingly dominated by faunal crusts – primarily barnacles and encrusting bryozoans. Only small patches of algal crusts were

present. This was a grazed/sediment affected community (subject to grazing from urchins and scouring from current-driven sand from nearby areas of mixed sediment). Typified by patches of *Parasmittina*, expanses of *Balanus crenatus* (with large areas of basal plates only) and very sparse *Alcyonium* (small colonies only).



Plate 6.21 Juvenile sunstar (*Crossaster papposus*), barnacles and bryozoans (Transect 7-8, Habitat 1).



Plate 6.22 Boulder with velvet swimming crab (*Necora puber*), barnacles (*Balanus* sp.), bryozoans (*Parasmittina* sp.), seaweed (*Desmarestia aculeata*) and urchins (*Echinus esculentus*), (Transect 7-8 Habitat 2).

6.4.4.3 <u>Dive 2/ Transect 7-8 - General classification (c) - Sediment-affected or disturbed kelp and seaweed communities - EUNIS A3.12</u>

Infralittoral rock habitats, subject to disturbance through mobility of the substratum (boulders or cobbles) or abrasion/covering by nearby coarse sediments or suspended particulate matter (sand).

<u>Dive 2/Transect 7-8: Habitat 3 – Mixed kelps with scour-tolerant and opportunistic foliose red seaweeds on scoured or sand-covered infralittoral rock – EUNIS A3.125</u>

Bedrock and boulders, often in tide-swept areas, that are subject to scouring or periodic burial by sand, characterised by a canopy of mixed kelps and the brown seaweed *Desmarestia aculeata*.



Plate 6.23 Mixed kelps and scour-tolerant weeds, T7-8 (Transect 7-8 Habitat 3)..



Plate 6.24 Cobble supporting a sponge colony (*Cliona celata*) & opportunistic foliose red weeds. A variety of encrusting fauna are visible (bryozoans, polychaetes and barnacles) (Transect 7-8)



Plate 6.25 Starfish (Stichastrella rosea) on mixed sediment, (Transect 7-8).

6.4.5 DIVE 3 - Transect between ROV Stations 8 & 9 (Depth 16.5-12.2m)

The following habitats were identified on T8-9:

- Circalittoral mixed sediments
 - o F. foliacea & H. falcata on tide-swept circalittoral mixed sediment
- Echinoderms & crustose communities on circalittoral rock
 - o Flustra foliacea on slightly scoured silty circalittoral rock
 - Faunal & algal crusts with P. triqueter & sparse A. digitatum on exposed to moderately wave-exposed circalittoral rock
- Sediment-affected or disturbed kelp and seaweed communities
 - Mixed kelps with scour-tolerant and opportunistic foliose red seaweeds on scoured or sand-covered infralittoral rock

Brief seafloor description

One dive transect was carried out between Stations 8 and 9. The beginning of the transect was characterised by boulder field and outcropping bedrock on mixed sublittoral sediment with *Flustra*, *Delesseria* and sparse *L. hyperborea* at a depth of 16.5m. Mixed sediment here appeared sand-swept but stable. A bedrock ledge was encountered midway on the transect. A gravel/sand flat was encountered above the level of this ledge. The upper end of the transect was composed of a boulder field on mixed sediment with a sediment affected kelp and seaweed community at a depth of 12.2m.

6.4.5.1 <u>Dive 3/Transect 8-9 - General classification (a) - Circalittoral mixed sediments - EUNIS</u> A5.44

<u>Dive 3/Transect 8-9: Habitat 1 – Flustra foliacea and Hydrallmania falcata on tide-swept circalittoral mixed sediment – EUNIS A5.444</u>

A habitat on circalittoral mixed circalittoral sediment (sand, shell,pebble and cobble with occasional boulders). The habitat category roughly fits the depth, community and substrate. However the species composition is quite different – less hydroid and more algal and bryozoan-dominated (notabe bryozoans *Cellaria sinuosa* and *Crisia sp.* and algae include *Delesseria*, *Heterosiphonia* and *Callophyllis*).



Plate 6.26 Variety of encrusting fauna/flora on mixed sediment, (Transect 8-9)

6.4.5.2 <u>Dive 3/Transect 8-9- General classification (b) – Echinoderms and crustose</u>
communities on circalittoral rock – EUNIS A4.21

<u>Transect 8-9: Habitat 2 – Flustra foliacea on slightly scoured silty circalittoral rock – EUNIS A4.2141</u>

This variant is typically found on the upper faces of moderately wave-exposed circalittoral bedrock or boulders subjected to moderately strong tidal streams.



Plate 6.27 Boulder with bryozoans (Flustra foliacea), seaweed (Delesseria sanguinea) and other encrusting flora and fauna (Transect 8-9)

6.4.5.3 <u>Dive 3/Transect 8-9: Habitat 3 – Faunal and algal crusts with *Pomatoceros triqueter* and sparse *Alcyonium digitatum* on exposed to moderately wave-exposed circalittoral rock – <u>EUNIS A4.2145</u></u>

A fractured bedrock ledge was encountered mid-transect this was dominated by algal and bryozoan crusts. Most of the large boulders were dominated by a similar community. This was a sediment affected community. Typified by patches of *Parasmittina*, expanses of *Lithophyllum*, tube worms (*Pomatoceros* sp.) and very sparse *Alcyonium* (very small colonies only).



Plate 6.28 Bedrock ledge encountered on Transect 8-9

6.4.5.4 <u>Dive 3/Transect 8-9 - General classification (c) - Sediment-affected or disturbed kelp and seaweed communities - EUNIS A3.12</u>

Transect 8-9: Habitat 4 – Mixed kelps with scour-tolerant and opportunistic foliose red seaweeds on scoured or sand-covered infralittoral rock – EUNIS A3.125



Plate 6.29 Mixed kelp community on sand-scoured rocks, Transect 8-9



Plate 6.30 Starfish (Leptasterias muelleri) on cobbles, Transect 8-9,



Plate 6.31 Urchin (Echinus esculentus) among encrusted kelp stipes & rock, Transect 8-9.



Plate 6.32 Unusual rock heap with urchin & foliose reds on Transect 8-9

6.4.6 DIVE 4 – Located at ROV Station 17 (Depth 33m)

The following habitats were identified at Station 17:

- Circalittoral mixed sediments
 - o F. foliacea & H. falcata on tide-swept circalittoral mixed sediment
 - Sandy mixed sediment with A. diaphanum

Brief seafloor description:

One dive was carried out at Station 17 at a depth of 33m. One broad habitat classification was identified – Circalittoral mixed sediments. At this station sediments were composed of sand and shelly gravel with some stone pebbles. Fauna was sparse and largely consisted of sand-tolerant erect bryozoans. A substantial amount of mussel shell was noted.

6.4.6.1 <u>Dive4/Station 17 General classification (a) – Circalittoral mixed sediments - EUNIS A5.44</u>

<u>Dive 4/Station 17: Habitat 1/2 – F. foliacea & H. falcata on tide-swept circalittoral mixed sediment – (A5.444 Sandy mixed sediment with A. diaphanum – (A5.446)</u>

A habitat on circalittoral mixed sediment (sand, shell, pebble and cobble with occasional boulders). Faunal cover was sparse with occasional *Flustra* and *Securiflustra*.



Plate 6.33 Dragonet (Callionymus lyra) on circalittoral mixed sediment, Station 17

As was the case for most of the stations investigated during the dive work, habitats were patchy with variation in the species composition of communities – even over short distances

at a single station. Parts of the seafloor at this station could best be described as sandy mixed sediment with *Alcyonidium diaphanum* (A5.446) – a proposed new unit of the EUNIS classification (Southampton workshop).



Plate 6.34 Tide-swept circalittoral mixed sediments typical of Station 17.



Plate 6.35 Starfish (*A. rubens & C. papposus* juv), bryozoans (*Securiflustra* sp.), Station 17.



Plate 6.36 Brittlestar (Ophiura sp.) on circalittoral mixed sediments, Station 17



Plate 6.37 Sponge (Stelligera stuposa) on mixed sediments, Station 17

6.4.7 DIVE 5 – Located at ROV Station 19 (Depth 27m)

The following habitats were identified at Station 19:

- Circalittoral mixed sediments
 - Flustra foliacea and Hydrallmania falcata on tide-swept circalittoral mixed sediment
- · Echinoderms & crustose communities on circalittoral rock
 - Faunal & algal crusts with P. triqueter & sparse A. digitatum on exposed to moderately wave-exposed circalittoral rock

Brief seafloor description:

One dive was carried out at Station 19 at a depth of 27m. Two broad habitat classifications were identified – Circalittoral mixed sediments and Echinoderms and crustose communities on circalittoral rock. At this station the seafloor was composed of sand and shelly gravel with some stone pebbles and occasional boulders. Fauna was sparse and largely consisted of sand-tolerant erect bryozoans.

6.4.7.1 <u>Dive 5/Station 19 - General classification (a) - Circalittoral mixed sediments - EUNIS</u> A5.44

<u>Dive 5/Station 19: Habitat 1 – Flustra foliacea and Hydrallmania falcata on tide-swept circalittoral mixed sediment – EUNIS A5.444</u>

A habitat on circalittoral mixed circalittoral sediment (sand, shell, pebble and cobble with occasional boulders). The habitat category roughly fits the depth, community and substrate. Greater faunal cover was recorded than for the same habitat classification on Station 17. Substantial amounts of *Flustra* were noted along with other sand-tolerant bryozoans such as *Eucratea* and *Cellaria*. Hydroids did not contribute substantially to community species composition.



Plate 6.38 Bryozoan-dominated community on mixed sediment. The main species visible are *Flustra foliacea, Eucratea loricata* and *Cellaria sinuosa,* Station 19.

6.4.7.2 <u>Dive 5/Station 19 - General classification (b) - Echinoderms and crustose communities</u> on circalittoral rock - EUNIS A4.21

<u>Dive 5/Station 19 Habitat 2 – Faunal and algal crusts with Pomatoceros triqueter and sparse</u>
<u>Alcyonium digitatum on exposed to moderately wave-exposed circalittoral rock – EUNIS A4.2145</u>

Several boulders were encountered that were overwhelmingly dominated by faunal crusts – primarily barnacles and encrusting bryozoans and hydroids. Only small patches of algal crusts were present. This was a grazed/sediment affected community (subject to grazing from urchins and scouring from current-driven sand from nearby areas of mixed sediment). Typified by patches of *Parasmittina*, expanses of *Balanus crenatus* (with some large areas of basal plates).



Plate 6.39 Encrusted boulder with urchins (Echinus esculentus), bryozoans and an edible crab (Cancer pagurus), Station 19



Plate 6.40 Dwarf cuttlefish (Sepiola atlantica) among bryozoans, Station 19



Plate 6.41 Sunstar feeding on brittlestars among bryozoans, Station 19

6.4.8 DIVE 6 - 250m SE of Station 19 (Depth 27.5m)

The following habitats were identified 250m SE of Station 19:

- Circalittoral mixed sediments
 - Flustra foliacea and Hydrallmania falcata on tide-swept circalittoral mixed sediment
 - Sandy mixed sediment with Alcyonidium diaphanum

Brief seafloor description

One dive was carried out 250m SE of Station 19 at a depth of 27.5m. One broad habitat classification was identified – Circalittoral mixed sediments. At this station sediments were composed of sand and shell/stone gravel with some cobbles. Fauna was sparse and largely consisted of sand-tolerant erect bryozoans.

6.4.8.1 <u>Dive 6/250m SE of Station 19 General classification (a) – Circalittoral mixed sediments</u> - EUNIS A5.44

250m SE of Station 19: Habitat 1/2 – Flustra foliacea and Hydrallmania falcata on tide-swept circalittoral mixed sediment – EUNIS A5.444/Sandy mixed sediment with Alcyonidium diaphanum – EUNIS A5.446

The EUNIS description for this habitat has been given in section 6.4.6.1 of this report. EUNIS 5.446 is a proposed new unit.

A habitat on circalittoral mixed sediment (sand, shell, pebble and cobble with occasional boulders). The habitat category roughly fits the depth, community and substrate of both of the above habitats. Boulders were not encountered. Faunal cover was sparse with *Flustra* (rare) and other sand tolerant bryozoans encountered.



Plate 6.42 Bryozoans (*Flustra sp.* and *Alcyonidium* sp.) on circalittoral mixed sediments, 250m SE of Station 19



Plate 6.43 Sunstar (Crossaster papposus) & A. diaphanum, 250m SE of Station 19



Plate 6.44 Bryozoans (*Flustra & Cellaria*), hydroid (*Hydrallmania falcata*) 250m SE of Station 19

6.4.9 DIVE 7 - 250m NW of ROV Station 19 (Depth 27m)

The following habitats were identified 250m NW of Station 19:

- Circalittoral mixed sediments
 - Flustra foliacea and Hydrallmania falcata on tide-swept circalittoral mixed sediment

Brief seafloor description:

One dive was carried out 250m NW of Station 19 at a depth of 27m. One broad habitat classification was identified – Circalittoral mixed sediments. At this station sediments were composed of sand with primarily stone gravel and more cobbles than seen 250m NW of Station 19 – a coarser substrate. Fauna was less sparse than was seen 250m NW of Station 19 and largely consisted of sand-tolerant erect bryozoans with a slightly greater cover of *Cellaria* and *Eucratea*. The seafloor consisted of sand and some silt with pebbles, cobbles and small boulders and was apparently tide-swept but stable.

6.4.9.1 <u>Dive 7/250m NW of ROV Station 19 - General classification (a) - Circalittoral mixed</u> sediments - EUNIS A5.44

<u>Dive 7/250m NW of Station 19: Habitat 1 – Flustra foliacea and Hydrallmania falcata on tide-swept circalittoral mixed sediment – EUNIS A5.444</u>

A habitat on circalittoral mixed sediment (sand, shell, pebble and cobble with occasional boulders). The habitat category roughly fits the depth, community and substrate of the above habitat. Boulders were not encountered. Faunal cover was less sparse than at the previous station with occasional *Flustra*, *Cellaria* and other sand tolerant bryozoans encountered.

6-57



Plate 6.45 Mixed sediment seafloor 250m NW of Station 19.

The subject of the shot is a starfish (*Stichastrella rosea*). Also visible are bryozoans, (*F. foliacea*, *C. sinuosa* and *Crisia* sp.) and a polychaete *Thelepus* sp. The mixed nature of the sediment is obvious – sand, shell, pebbles and cobbles are all visible.



Plate 6.46 Polychaete tubes (*Bispira* sp. & *Chaetopterus* sp.) & bryozoans, 250m NW of Station 19



Plate 6.47 Urchin (E. esculentus), 250m NW of Station 19

6.4.10 DIVE 8 - Transect between ROV Stations 20 & 21 (Depth 20m - 15m)

The following habitats were identified on T20-21:

- Circalittoral mixed sediments
 - Sandy mixed sediment with Alcyonidium diaphanum
 - o F. foliacea & H. falcata on tide-swept circalittoral mixed sediment
- · Echinoderms & crustose communities on circalittoral rock
 - Faunal & algal crusts with P. triqueter & sparse A. digitatum on exposed to moderately wave-exposed circalittoral rock

Brief seafloor description:

One dive was carried out on a transect between stations 20 and 21. Two broad habitat classifications were identified – Circalittoral mixed sediments and Echinoderms and crustose communities on circalittoral rock. On this transect sediments were composed of sand with primarily stone gravel and some cobbles. Cobbles became more frequent with decreasing depth and some small boulders were encountered towards the end of the transect. Fauna largely consisted of sand-tolerant erect bryozoans. Brittlestars (Ophiura sp.) were common in places along this transect. A number of scallops (*Pecten maximus*) were also encountered along the transect. The dive began at a depth of 20m and ended at a depth of approximately 15m.

<u>6.4.10.1</u> <u>Dive 8/Transect between Stations 20 & 21 - General classification (a) - Circalittoral mixed sediments - EUNIS A5.44</u>

<u>Dive 8/Transect between Stations 20 & 21: Habitat 1 – Sandy mixed sediment with Alcyonidium diaphanum – EUNIS A5.446</u>

A (proposed new) habitat on circalittoral mixed sediment (sand, shell, pebble and occasional cobble) at the deep end of this transect. The habitat category roughly fits the depth, community and substrate of the above habitat. Boulders were not encountered. Faunal cover was more sparse at the beginning of the transect and increased as the seafloor coarsened.



Plate 6.48 King scallop (Pecten maximus) on mixed sediments. Transect 20-21.

Numerous brittlestars (*Ophiura* sp.) polychaetes, barnacles and bryozoans are also visible.

<u>Dive 8/Transect between Stations 20 & 21: Habitat 2 – Flustra foliacea and *Hydrallmania* falcata on tide-swept circalittoral mixed sediment – *EUNIS A5.444*</u>

A habitat on circalittoral mixed sediment (sand, shell, pebble and occasional cobbles). The habitat category roughly fits the depth, community and substrate of the above habitat. Boulders were not encountered. Faunal cover was more sparse at the beginning of the transect and increased as the seafloor coarsened.



Plate 6.49 A variety of bryozoans (*Flustra* sp., *Securiflustra* sp. & *Cellaria* sp.), numerous brittlestars (*Ophiura* sp.), barnacles (*Balanus* sp.) on mixed sediment Transect 20-21

<u>6.4.10.2</u> <u>Dive 8/Transect between Stations 20 & 21 - General classification (b) - Echinoderms and crustose communities on circalittoral rock - EUNIS A4.21</u>

<u>Transect between Stations 20 & 21: Habitat 3 – Faunal and algal crusts with *Pomatoceros* <u>triqueter</u> and sparse <u>Alcyonium digitatum</u> on exposed to moderately wave-exposed <u>circalittoral rock – EUNIS A4.2145</u></u>

Several boulders were encountered that were dominated by faunal crusts – primarily barnacles and encrusting bryozoans and hydroids. Only small patches of algal crusts were present if at all at these depths. This was a grazed/sediment affected community (subject to grazing from urchins and scouring from current-driven sand from nearby areas of mixed sediment). Typified by patches of *Parasmittina*, expanses of *Balanus crenatus* and *Parasmittina* sp.



Plate 6.50 Starfish (Asterias rubens) and urchin (Echinus esculentus) on a sand-swept, encrusted boulder, Transect 20-21



Plate 6.51 Crab (C. pagurus), bryozoans and encrusting fauna, Transect 20-21



Plate 6.52 Bryozoans (Securiflustra sp., Eucratea sp.) on mixed sediments, Transect 20-21

6.4.11 DIVE 9 - Transect between ROV Stations 22 & 23 (Depth 14m - 8m)

The following habitats were identified on T22-23:

- Circalittoral mixed sediments
- Kelp with cushion fauna and/or foliose red seaweeds
 - Laminaria hyperborea park with dense foliose red seaweeds on exposed lower infralittoral rock
- Sediment-affected or disturbed kelp and seaweed communities
 - Mixed kelps with scour-tolerant and opportunistic foliose red seaweeds on scoured or sand-covered infralittoral rock

Brief seafloor description:

One dive was carried out on a transect between the locations of ROV stations 22 and 23. Two broad habitat classifications were identified – Infralittoral mixed sediments and Kelp with cushion fauna and/or foliose red seaweeds (also characterised as Sediment-affected or disturbed kelp and seaweed communities). This transect began on sediments that were composed of sand with primarily stone gravel and some cobbles at a depth of 14m. Occasional boulders were encountered. With decreasing depth this moved on to outcrops of fractured bedrock with boulders and patches of mixed sediment with a kelp community. The dive ended at a depth of 8m.

6.4.11.1 <u>Dive 9/Transect beween ROV Stations 22 & 23 General classification (a) – Infralittoral mixed sediments - EUNIS A5.43</u>

Shallow mixed (heterogeneous) sediments in fully marine or near fully marine conditions, supporting various animal-dominated communities, with relatively low proportions of seaweeds.



Plate 6.53 Mixed sediments with a common starfish (Asterias rubens) T22-23, Nov 2009

6.4.11.2 <u>Dive 9/Transect beween ROV Stations 22 & 23 General classification (b) – Patches of Infralittoral mixed sediments (A5.43) and Kelp with cushion fauna and/or foliose red seaweeds – EUNIS A3.11 and/or Sediment-affected or disturbed kelp and seaweed communities EUNIS A3.12</u>

EUNIS A3.11 Rocky habitats in the infralittoral zone subject to exposed to extremely exposed wave action or strong tidal streams. Typically the rock supports a community of kelp *Laminaria hyperborea* with foliose seaweeds and animals, the latter tending to become more prominent in areas of strongest water movement.

<u>Dive 9/Transect between Stations 22 & 23: Habitat 2(i) – Laminaria hyperborea park with dense foliose red seaweeds on exposed lower infralittoral rock – EUNIS A3.1152</u>

Very exposed to exposed lower infralittoral bedrock or large boulders characterised by a kelp park of *Laminaria hyperborea* with a dense turf of foliose red seaweeds and encrusting coralline algae.



Plate 6.54 Kelp park with encrusted stipes and urchin (*E. esculentus*), foliose red seaweeds, silt and coralline algae, Transect 22-23

<u>Dive 9/Transect 22-23: Mixed kelps with scour-tolerant and opportunistic foliose red</u> seaweeds on scoured or sand-covered infralittoral rock – EUNIS A3.125

Bedrock and boulders, often in tide-swept areas, that are subject to scouring or periodic burial by sand, characterised by a canopy of mixed kelps such as *Laminaria saccharina*, *Laminaria hyperborea* and *Saccorhiza polyschides* and the brown seaweed *Desmarestia aculeata*; there may also be an understorey of foliose seaweeds that can withstand scour such as *Plocamium cartilagineum*, *Chondrus crispus*, *Dilsea carnosa*, *Callophyllis laciniata* as well as the filamentous *Heterosiphonia plumosa* and the foliose brown seaweed *Dictyota dichotoma*.



Plate 6.55 Mixed kelps with encrusted stipes, and scour tolerant red seaweeds. This habitat was found adjacent to areas of mixed sediments on Transect 22-23



Plate 6.56 Urchin, cup corals (*Caryophyllia smithii*) & coralline algae on boulder, Transect 22-23



Plate 6.57 Lobster emerging from beneath encrusted boulders, Transect 22-23

6.4.12 DIVE 10 - Transect between ROV Stations 31 & 32 (Depth 26.4m - 27.1m)

The following habitats were identified on T31-32:

- Circalittoral mixed sediments
 - Sandy mixed sediment with Alcyonidium diaphanum
 - Flustra foliacea & Hydrallmania falcata on tide-swept circalittoral mixed sediment

Brief seafloor description:

One dive was carried out on a transect between stations 31 and 32. One broad habitat classification was identified – Circalittoral mixed sediments. On this transect sediments were composed of sand with primarily stone gravel, some shell gravel and some cobbles. Distribution of cobbles was patchy. Fauna largely consisted of sand-tolerant erect bryozoans and barnacles. The dive began on a stable but sand-swept pebble gravel and sand seafloor at a depth of 26.4m. The substrate became slightly coarser on moving shoreward with some cobbles on the end of the transect (21.7m).

<u>6.4.12.1</u> <u>Dive 10/Transect between Station 31 & 32 General classification (a) – Circalittoral mixed sediments - EUNIS A5.44</u>

<u>Dive 10/Transect between Stations 31 & 32: Habitat 1 – Sandy mixed sediment with</u> Alcyonidium diaphanum – *EUNIS A5.446*

A (proposed new) habitat on circalittoral mixed sediment (sand, shell, pebble and occasional cobble) in patches all along this transect. The habitat category roughly fits the depth, community and substrate of the above habitat. A mix of erect bryozoan species were also encountered at this station.

<u>Dive 10/Transect between Stations 31 & 32: Habitat 2 –Flustra foliacea and Hydrallmania falcata on tide-swept circalittoral mixed sediment – EUNIS A5.444</u>

A habitat on circalittoral mixed sediment (sand, shell, pebble and occasional cobbles). The habitat category roughly fits the depth, community and substrate of the above habitat. This area was quite sand-scoured/grazed and faunal cover was sparse with only small colonies recorded. Colonies of *Eucratea* were more frequently encountered than those of *Flustra* or *Securiflustra*.



Plate 6.58 *Alcyonidium* sp. & other bryozoans on mixed sublittoral sediments, Transect 31-32



Plate 6.59 Mixed sublittoral sediments with erect bryozoans (*Flustra* sp., *Securiflustra* sp. and *Eucratea* sp.), and barnacles, Transect 31-32



Plate 6.60 Erect bryozoan colony (*E. Ioricata*) on circalittoral mixed sediment, Transect 31-32

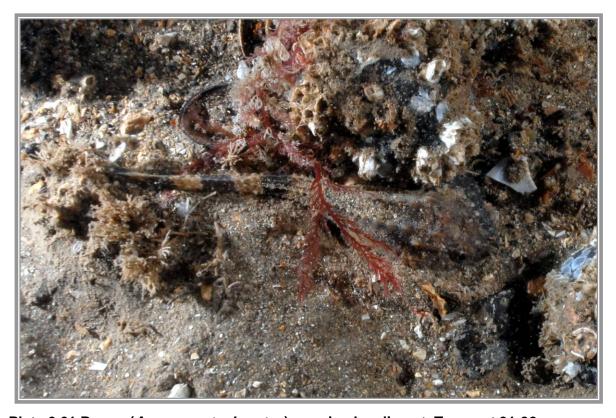


Plate 6.61 Pogge (Agonus cataphractus) on mixed sediment, Transect 31-32



Plate 6.62 Dragonet (Callionymus lyra) and erect bryozoan colonies, Transect 31-32



Plate 6.63 Anemone (Actinothoe sphyrodeta) on mixed sediments

6.4.13 DIVE 11 - Transect between ROV Stations 32 & 33 (Depth 16.2m - 10.3m)

The following habitats were identified on T32-33:

- Circalittoral mixed sediments/Infralittoral mixed sediments
 - o F. foliacea and H. falcata on tide-swept circalittoral mixed sediment
- Kelp with cushion fauna and/or foliose red seaweeds
- · Sediment-affected or disturbed kelp and seaweed communities
 - Mixed kelps with scour-tolerant and opportunistic foliose red seaweeds on scoured or sand-covered infralittoral rock
- Echinoderms and crustose communities on circalittoral rock
 - Caryophyllia smithii, sponges and crustose communities on wave-exposed circalittoral rock

Brief seafloor description:

One dive was carried out on a transect between stations 32 and 33. Three broad habitat classifications were identified – Circalittoral/Infralittoral mixed sediments and Sediment-affected or disturbed kelp and seaweed communities. This transect began on sediments that were composed of sand with primarily stone gravel and some cobbles. Occasional boulders were encountered. The community present was primarily bryozoan based with *Flustra* and *Eucratea* most prominent. With decreasing depth this moved on to mixed infralittoral sediment with outcrops of fractured bedrock and boulders supporting a sediment-affected kelp community. Underwater visibility was rather poor during this dive at between 2 and 4m. Water depth at the beginning of this dive was 16.2m and at its end was 10.3m.

6.4.13.1 <u>Dive 11/Transect 32-33 - General classification (a) - Infralittoral/Circalittoral</u> mixed sediments - EUNIS A5.43/5.44

The depth of this site matches the Infralittoral habitat classification whilst the community make-up matches the Circalittoral habitat classification. This transect begins on essentially the same habitat as the previous transect left off. Patches of mixed sediment were encountered throughout the transect.

<u>Dive 11/Transect between Stations 32 & 33: Habitat 2 – Flustra foliacea and H. falcata on tide-swept circalittoral mixed sediment – EUNIS A5.444</u>

A habitat on circalittoral mixed sediment (sand, shell, pebble and occasional cobbles and small boulders). The habitat category roughly fits the community and substrate of the above habitat though the depth is slightly shallow. Colonies of *Flustra* and *Eucratea* were the most obvious members of the faunal community.

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Plate 6.64 Tide-swept bryozoan-dominated community – mixed sediments and boulders

6.4.13.2 <u>Dive 11/Transect 32-33 General classification (b) – Kelp with cushion fauna</u>
and/or foliose red seaweeds – EUNIS A3.11 and/or Sediment-affected or disturbed kelp
and seaweed communities EUNIS A3.12

Dive 11/Transect between Stations 32 & 33: Habitat 2 – Mixed kelps with scour-tolerant and opportunistic foliose red seaweeds on scoured or sand-covered infralittoral rock – EUNIS A3.125



Plate 6.65 Mixed kelps with scour tolerant/opportunistic red seaweeds, Transect 32-33.

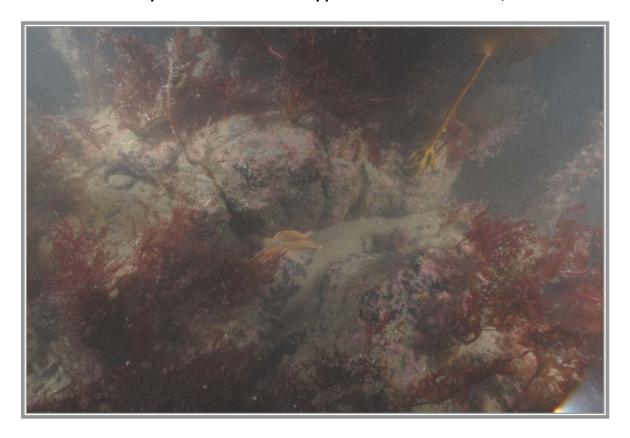


Plate 6.66 Kelps, starfish and mixed reds on boulders and bedrock, Transect 32-33.

6.4.13.3 <u>Dive 11/Transect 32-33 - General classification (c) - Echinoderms and crustose</u> communities on circalittoral rock - EUNIS A4.21

<u>Dive 11/Transect between Stations 32 & 33: Habitat 3 – Caryophyllia smithii, sponges and crustose communities on wave-exposed circalittoral rock – EUNIS A4.212</u>

This biotope typically occurs on the upper and vertical faces of wave-exposed, moderately strong to weakly tide-swept, circalittoral bedrock or boulders, with a water depth range of 20-30m. The habitat encountered during the current survey work roughly fits this habitat classification – albeit at a shallower depth and with fewer sponges.



Plate 6.67 Encrusted boulder with cup corals (*C. smithii*), bryozoans, (*Parasmittina sp.*), velvet swimming crab (Necora puber), encrusting coralline alga (Lithophyllum sp.) and decaying sea beech (*Delesseria sanguinea*), Transect 32-33.



Plate 6.68 Urchin (*Echinus esculentus*) on encrusted boulder, Transect 32-33.



Plate 6.69 Sponge Polymastia penicillus, bryozoans (Crisia sp. and *Eucratea sp.*), Transect 32-33.

6.4.14 DIVE 12 – Located at ROV Station 41 (Depth 5.2m)

A single habitat was identified at Station 41 – sublittoral sand.

Brief seafloor description:

One dive was carried out at Station 41 at a maximum depth of 5.2m. Sand-tolerant seaweeds, sponges, crabs and aneomnes were recorded.

6.4.14.1 Dive 12/Station 41 – sublittoral sand - EUNIS A5.2

The seafloor here was characterised by fine sand with occasional shell fragments. Numerous old oyster (*Ostrea edulis*) shells were recorded. Sand tolerant seaweed (*Ahnfeltia plicata*) and anemones (*Sagartiogeton laceratus*) were noted on shells – these shells were generally covered in a thin layer of sand. A substantial amount of plant material was noted drifting along with the current.



Plate 6.70 Swimming crab (*Liocarcinus depurato*r) on sand with sand-tolerant seaweed (*Ahnfeltia plicata*) and anemones (*Sagartiogeton laceratus*).



Plate 6.71 Sponge (Suberites ficus), fish (Pomatoschistus sp.), weed (A. plicata), Station 41.



Plate 6.72 Anemones (*S. laceratus*) and sponge (*Cliona celata*) on old oyster shells, Station 41.

6.4.15 Habitat map

A habitat map was drawn up based on information gained from:

- 12 dives on the site carried out by AQUAFACT in November 2009
- Video camera drops at each station carried out by Aquatic Services Unit, Cork in October 2009
- Information from 4 additional dive sites (NIEA/CEDaR, 1983, 2006)

Based on the results of the above underwater investigations a map showing the expected habitat distributions at the site was drawn up (habitat types were primarily based on information taken from the 12 dive sites). Where possible a habitat was assigned to each station. These were then mapped using GIS (see Figure 60).

6.4.15.1 Habitat distribution

Subtidal habitats are generally distributed in bands parallel to the shore. For the current study, where a number of adjoining stations were characterised by the same habitat type (stations 6, 8, 9 15, 23, 33, 36 for example) a polygon representing this habitat type was placed on the map encompassing these stations and the areas between them. Depth contours on the Admiralty chart were used as a guide in delimiting upper and lower reaches of the various habitat types. The two main habitat types assigned are:

- · A5.44 Circalittoral mixed sediments and
- A3.12 sediment-affected or disturbed kelp and seaweed communities.

In many cases there is a degree of overlap in habitat distribution where patches of one habitat alternate with those of another – echinoderm/crustose communities on rock in an area primarily characterised by circalittoral mixed sediments for example.

Table 6.4 Habitats assigned to stations on the Portmuck site.

EUNIS	Habitat type	Stations			
A3.11	Kelp with cushion fauna and/or foliose red seaweeds	23			
A3.12	Sediment-affected or disturbed kelp and seaweed communities	6, 8, 9, 14, 15, 22, 24, 30, 33, 36, 38			
A4.21	Echinoderms and crustose communities on circalittoral rock	3, 22, 29, 32, 35			
A5.2	Sublittoral sand	5, 29, 30, 39, 40, 41			
A5.43	Infralittoral mixed sediments	15, 23, 33, 36, 38			
A5.44	Circalittoral mixed sediments	1, 2, 4, 7, 10, 13, 16, 17, 19, 21, 22, 27, 28, 31, 32, 34, 35, 37			

(This information was used to draw up the habitat map presented in Figure 6.6)

Figure 6.6 Habitat Map

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6.5 SEDIMENT INFAUNAL SURVEY.

On behalf of RPS Group, Aquatic Services Unit undertook a biological survey of the benthos in the immediate vicinity of a proposed brine outfall, near Islandmagee, Co. Antrim.

6.5.1 Methodology

Fieldwork was carried out on the 26th January 2010. Sub-tidal dredge samples were taken with a modified anchor dredge sampler deployed from a boat. Subtidal grab samples were taken using a 0.1m² Stainless Steel Van-Veen Grab. All sampling positions were recorded using the onboard differential GPS. A complete list of stations sampled and displayed on a map are given in Table I and Figure 1.

Table 6.5 Positions of benthic sampling stations.

Station		Co-ordinates				
		Latitude	Longitude			
		Grab Samples				
Site 39		54°50.940" N	5°43.765" W			
Site 40		54°50.384" N	5°46.915" W			
Site 41		54°50.042" N	5°46.423" W			
		Anchor Dredge Samples				
10.40	In	54°51.568" N	5°44.506" W			
10 AD	Out	54°51.658" N	5°44.670" W			
17 AD	In	54°51.561" N	5°44.462" W			
17 AD	Out	54°51.632" N	5°44.613" W			
10.40	In	54°51.476" N	5°44.544" W			
19 AD	Out	54°51.493" N	5°44.579" W			
42.40	In	54°51.691"N	5°45.364" W			
42 AD	Out	54°51.758" N	5°45.516" W			
42.40	In	54°51.641" N	5°44.785" W			
43 AD	Out	54°51.617" N	5°44.674" W			
45.40	In	54°51.664" N	5°44.344" W			
45 AD	Out	54°51.732" N	5°44.521" W			
47 AD	In	54°51.729" N	5°44.230" W			
47 AD	Out	54°51.796" N	5°44.461" W			
50 AD	In	54°51.287" N	5°43.731" W			
52 AD	Out	54°51.370" N	5°43.857" W			
E2 AD	In	54°51.431" N	5°44.103" W			
53 AD	Out	54°51.470" N	5°44.202" W			
E4 AD	In	54°51.581" N	5°44.644" W			
54 AD	Out	54°51.546" N	5°44.557" W			

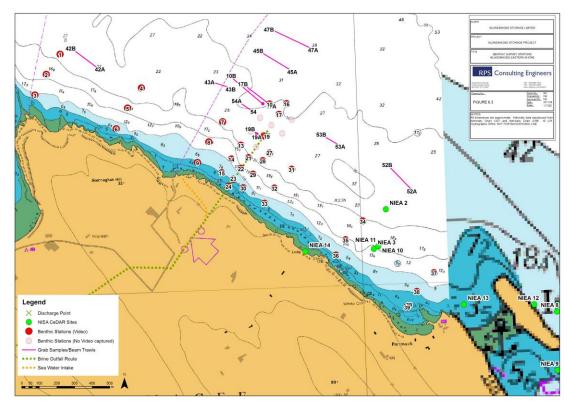


Figure 6.7 Map showing locations of Anchor Dredge samples across the survey sites.

Dredge sampling locations are marked by pink lines.

6.5.2 Sub-tidal Dredge Samples

At each sample station, a single anchor dredge sample was obtained. The anchor dredge was deployed 20 m in advance of the target and sufficient warp was paid out. The dredge was then towed for several minutes to allow for a suitable sample volume to be collected. Where this proved unsuccessful, the process was repeated and the anchor dredge was dragged a further distance.

After successful deployment and retrieval of the anchor dredge, the sample was transferred to a large container and labelled. Field notes were taken to include information such as sample number, date and time of sampling, a visual description of the sample, an estimate of the volume of the sample and any other relevant information in relation to the sampling effort (Appendix 6.9).

Residue from the dredge samples was sub-sampled to collect 2 x 10 litres replicates which were sieved through a 1mm mesh using gentle puddling. The material, which was retained on the sieve, was transferred to a labelled container and fixed with 10% buffered formalin to a minimum final concentration of 4%. A waterproof label was then added to each sample bucket and the sample number was recorded.

6.5.3 Sub-tidal Grab Samples

A total of three stations were sampled using a 0.1m² Van-Veen Grab, in areas where sediment was known to be fine enough for adequate grab penetration. At each site, a single grab sample was taken. Samples were sieved through a 1.0mm mesh sieve and the residue was transferred to a labelled container and fixed with 10% buffered formalin to a minimum final concentration of 4%. Two grab samples were taken in Larne Lough (Stations 40 and 41), while the third was on the outside of Islandmagee at Station 39 at Portmuck.

6.5.4 Sample Processing

Samples were manually sorted by eye, using a binocular microscope where necessary. Sorted samples were then stored in 70% alcohol until identification. Identifications were carried out by Unicomarine Ltd. (a company which have been implementing the NMBAQC scheme for marine invertebrate identification on behalf of its committee since its inception in 1994). Here the samples were identified to species level, where possible, counted and logged.

6.5.5 Data Analysis

On completion of the sample processing and identification the data was analysed using a variety of univariate and multivariate analyses to determine community structure.

Multivariate analysis was performed on the raw datasets using PRIMER v 5 (Clarke & Warwick, 1994). The data was subjected to a variety of multivariate analyses, including non-metric Multi Dimensional Scaling (MDS).

Detailed multivariate analysis was undertaken on the dredge data only. Samples were analysed using fourth-root transformation (countable data only) and presence/absence (to include the epifaunal data). Numbers of adults and juveniles of the same species were added for the analysis.

6.5.6 Results And Habitat Assessment

6.5.6.1 Anchor Dredge

The full data matrix, including abundance data is presented in Appendix 6.7 and Appendix 6.10. In total, there were 3,502 individuals from 257 countable taxa recorded in the present survey. There were an additional 92 attached and colonial taxa (including algae) recorded, resulting in 349 taxa in total recorded in the Anchor Dredge samples during the present survey.

Results from analysis of the countable data only and the data to include the epifaunal taxa produced very similar results. Analysis indicated the presence of a single community type in the area, with all sampling locations showing a large degree of similarity (>40%).

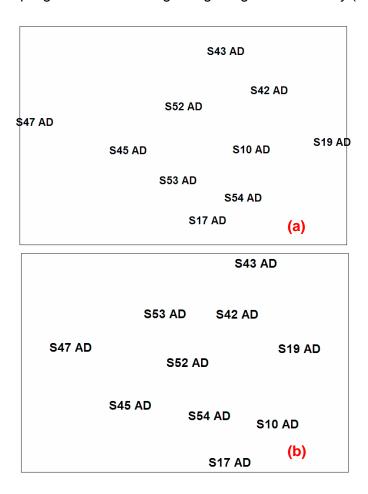


Figure 6.8 Multi-dimensional scaling plot of the faunal dredges across the survey site.

- (a) MDS plot of countable faunal data Stress = 0.14
- (b) MDS plot of presence/absence data of all identified taxa across the survey site Stress = 0.12

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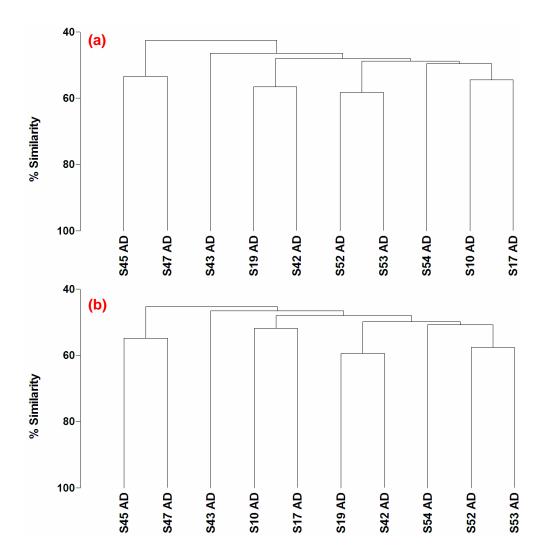


Figure 6.9 Cluster Diagram outlining the similarity between the sites across the survey site.

- (a) Cluster diagram of all countable fauna
- (b) Cluster diagram of presence/absence data of all identified taxa across the survey site.

Table 6.6 List of the most abundant Taxa

(where >60 individuals were recorded across the survey area) in descending order of abundance from the anchor dredge survey of January 2010.

	10AD	17AD	19AD	42AD	43AD	45AD	47AD	52AD	53AD	54AD	Total
Sabellaria spinulosa	31	27	69	99	14	5	3	126	36	88	498
Dendrodoa grossularia	24	14	25	17	3	1	2	0	2	188	276
Balanus crenatus	6	9	147	6	1	5	55	8	5	29	271
Balanus balanus	0	1	2	3	7	0	3	2	2	149	169
Leptochiton asellus	10	24	8	6	3	42	7	9	10	9	128
Serpulidae spp.	13	8	10	30	5	8	10	8	7	5	104
Hydroides norvegica	6	10	9	16	15	7	5	5	11	17	101
Glycera lapidum	2	12	5	4	3	15	12	4	11	11	79
Nemertea sp.	7	4	4	7	3	8	4	11	11	4	63
Pomatoceros triqueter	4	7	0	12	6	18	4	5	5	1	62

Table 6.7 Univariate descriptors of abundance and richness in the 10 dredge samples.

	Number of Taxa (No. of countable taxa)	Number of Individuals	Pielou's Evenness Index	Shannon- Wiener Diversity Index	Margalef's Species Richness
10AD	83 (60)	238	0.855	3.5	10.8
17AD	102 (69)	254	0.865	3.66	12.3
19AD	130 (101)	550	0.744	3.43	15.8
42AD	149 (106)	491	0.819	3.82	16.9
43AD	113 (71)	200	0.912	3.89	13.2
45AD	90 (69)	241	0.849	3.6	12.4
47AD	94 (62)	214	0.795	3.28	11.4
52AD	95 (74)	304	0.699	3.01	12.8
53AD	106 (77)	262	0.885	3.84	13.6
54AD	108 (83)	748	0.66	2.92	12.4

A single community type was identified across the survey site at Island Magee. This community type has been identified as Polychaete rich deep *Venus* community in offshore mixed sediments (EUNIS Code: A5.451).

6.5.7 Van-Veen Grabs

A total of 58 infaunal species were identified in the grab samples at three locations. A single station was located in Muck Bay on the eastern coast of Islandmagee. This site returned the lowest abundance and diversity (Table 4) and is classified as a mix of Infralittoral mobile clean sand with sparse fauna (EUNIS Code: A5.231) and *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand (EUNIS Code: A5.233). Two further stations were located along the western coast of Islandmagee, in Larne Lough. Both these sites are species rich (Table 4) and have been classified as *Ampelisca* spp., *Photis longicaudata* and other tube-building amphipods and polychaetes in infralittoral sandy mud (EUNIS Code: A5.335). A species abundance matrix is presented in Appendix 6.8.

Table 6.8 Univariate descriptors of abundance and richness in the 3 Grab samples.

	Number Taxa (No. countable taxa)	of of	Number of Individuals	Pielou's Evenness Index	Shannon- Wiener Diversity Index	Margalef's Species Richness
S39	7		15	0.878	1.71	2.22
S40	43		355	0.71	2.67	7.15
S41	32		165	0.842	2.92	6.07

6.6 ISLANDMAGEE STORAGE PROJECT BRINE DISCHARGE IMPACTS

6.6.1 Relevant Features of the Discharge

At maximum output of brine from the salt caverns, around 1000m³/hr will be discharged with an undiluted salt concentration of around 290g/l or about 8.5 times the salt concentration in seawater at the site, which ranges from 33-34g/l (i.e. 33-34 psu³) off Islandmagee. The brine will be discharged at a distance of about 450m off the eastern (outer) shore of Islandmagee at a depth of roughly 27m below low water. At this point the brine will mix with seawater and disperse away from the discharge point under the influence of tidal mixing forces, decreasing rapidly in concentration with distance. Due to the denser nature of the brine, dispersion and mixing will be confined to the deeper layers of the water column and it is in the communities along the seabed that the greatest impacts of the discharge can be expected to occur.

The brine will also be discharged at a temperature of 10°C above ambient, however this will result is an increase in temperature of just a fraction of one degree °C above ambient, imperceptible more than a few tens of metres away from the point of discharge (Figure 9.33 in Chapter 9.0 "Coastal Processes"). The impact of such a small and localised increase in ambient temperature would probably be very difficult to detect except within a few metres of the discharge. However, combined as it is with a relatively greater change in salinity, means that its impact will probably be indistinguishable from that of the salinity impact, and it is the latter which will be addressed in detail in the following assessment.

Three other potential features of the brine being discharged are important to note (i) the ionic composition, (ii) the level of heavy metal contaminants and (iii) the level of suspended solids. While historical data suggests that the salt deposits below Larne Lough are of a pure and high-quality nature, with low levels of contaminants, the precise ionic ratios i.e. of major ions such as Na $^+$, K $^+$, Cl $^-$, Mg $^{++}$, Ca $^{++}$ and SO $_4$ $^-$, are not known as yet, nor are the levels of potential impurities e.g. copper, zinc, cadmium etc. If the ratios of the major ions vary significantly from those in seawater, there could be adverse implications for invertebrates exposed to the diluted brine. Similarly, increased levels of heavy metals in the diluted brine would also have adverse impacts if the discharge gave rise to ambient heavy metal levels above a certain concentration. Finally, a significant increase in ambient suspended solids in the brine could result in adverse impacts in this area, particularly in sensitive, filter-feeding invertebrates, however this is unlikely given that only soluble material is extracted by the proposed solution mining technique.

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³ Psu – Practical Salinity Units – a measure of salt concentration, approximately equivalent to grams/litre

6.6.2 The Nature of Hypersaline Impacts

6.6.2.1 Overview of Impacts

The main anticipated impact from the proposed discharge is that it will lead to a localised increase in the ambient salinity, which will in turn give rise to potential adverse impacts, especially for marine invertebrates living on the seabed in the area surrounding the deepwater discharge point; the discharge will also have potential implications for marine algae (seaweeds). However, because of the much reduced abundance and diversity of algae in the deeper waters around the outfall, the significance of the impacts are expected to be minor compared to those which will be experienced by marine invertebrate species. The nature of these impacts will be associated with the exposure of organisms to salinity stress due to an increase in the ambient salinity levels above what for most species present will be their optimum or near optimum salinity for growth and survival. Sub-optimal salinities can have a wide range of impacts on organisms, the severity of which will vary from group to group and between individual species in each group (i.e. starfish, crabs, hydroids, bivalves etc.). Furthermore, the effects will vary between early development, juvenile and adult stages and in many cases between individuals of different body sizes within the same species.

The following is a list of the documented impacts caused by sub-optimal salinities:

- (i) Direct mortality
- (ii) Failure of fertilization
- (iii) Increased rates of abnormalities in embryos
- (iv) Delayed rates of development among embryonic and larval stages
- (v) Prolonged duration of planktonic stages
- (vi) Delayed settlement of larval stages
- (vii) Reduced growth rates
- (viii) Reduced reproductive output
- (ix) Avoidance of areas of sub-optimal salinity by mobile species

Each of these effects can have a greater or lesser impact on a community depending on the severity of the impact, its spatial extent and the status of that population in the impact zone. The impacts are mediated through the stress caused on the physiology of affected organisms by an increase in salinity above normal seasonal and inter-annual fluctuations. The cause and effect mechanisms of these impacts are not always fully understood and while there are similarities across all invertebrate groups, there are also very considerable differences in both the affect and the response in different species.

The following paragraphs present an overview the central role played by salinity in the biology of marine organisms and the extent to which organisms can adjust to changes in the ambient salinity, including changes outside of their normal range. The section also introduces some of the terms commonly used in describing the influence of salinity on marine invertebrates and plants.

6.6.3 Impacts Associated with Brine Discharges & How Organisms Adjust to these Changes

The main impact of the proposed discharge will be to raise the salinity of seawater within the mixing zone of the brine plume. While this will result in an increase in average salinities at any given point within the zone of influence of the plume, in reality it will result in fluctuating salinities at all points generated by tidally-induced directional changes in the plume. Thus organisms living in or on the bottom within the mixing zone will experience more or less rhythmic fluctuations in the salinity at and above the current background values of 33-34psu depending on their distance from the outfall point. How organisms and communities cope with these changes will determine the impact of the brine.

6.6.3.1 Overview of Osmoregulation

Evolutionary theory suggests that life first evolved in the marine environment followed by a gradual invasion of freshwater by some organisms; this later led to invasion of land. In the fully marine environment organisms, plant and animal, are generally exposed to very little fluctuation in ambient salinity and many of these organisms are confined to these waters, being unable to enter areas of decreased salinity such as estuaries. These organisms, which include the bulk of marine invertebrates, are termed stenohaline. Another group of organisms, which can enter estuaries for part or all of their life cycle and are thus able to tolerate a wider range of salinities, are termed euryhaline. The degree of euryhalinity is broad, so that certain species may penetrate into upper estuaries and near freshwater conditions, while others will be confined to mid-estuarine areas and so on. Saltmarsh habitats within estuaries often feature salinities above 33-34 psu at low tide because of windor sun-driven evaporation. A few euryhaline animals can cope with these hypersaline conditions too. Euryhaline animals can be further divided into two categories: osmoconformers and osmoregulators. Most euryhaline animals are osmoconformers when they are exposed to diluted seawater, their body fluids decrease in concentration until the internal and external salt concentrations are virtually identical. Many euryhaline osmoconformers (e.g. mussels, periwinkles, barnacles) can isolate themselves from the environment (by closure of the shells) if the water outside becomes too dilute. The remainder of euryhaline animals are osmoregulators - when they are exposed to lowered salinity they have the ability to keep their body fluids more concentrated than the medium outside. Examples include crabs and prawns.

6.6.3.2 Osmoregulation, Osmosis and Osmotic Pressure

The degree to which organisms can cope with fluctuations in salinity will depend on their capacity to either osmoconform or osmoregulate. *Osmoconformation* involves physiological regulation at the cellular level, but does not involve control of the blood concentration, which simply tracks that of the environment. *Osmoregulation* involves having a reduced skin permeability to salts and water, plus the ability to pump salts inward if the outside salinity is low. This permits the animal to maintain its body fluid concentrations within a much narrower range that than of osmoconformers and usually allows them to survive a

wider range of environmental salinities. Both types of euryhaline animal can survive wider ranges of salinity if these fluctuate (e.g. on a tidal basis), than if they are sustained.

Osmosis is the term that describes the tendency for water to flow across an osmotic pressure gradient on either side of a semi-permeable barrier (e.g. cell wall or gill tissue). Osmotic pressure is measured as osmolality and given in units of milliosmoles. It is determined by the total concentration of inorganic ions and/or small organic molecules (e.g. sugars), referred to collectively as osmolytes, which are present on either side of a semipermeable barrier. When the concentrations are in balance, then there is no net flow of water across the barrier and pressures at both sides are equal; they are said to be isomotic. Where the osmotic pressure outside is high or low relative to the internal pressure then there is a tendency for water to flow into or out of the organism. Thus when the external osmolyte concentration is low, as in dilute (hyposaline) estuarine waters, the tendency is for water to flow into the organism and its cells, which both tend to increase in volume, as these will have relatively higher concentrations of osmolytes. In contrast, in a hypersaline situation where the concentration of osmolytes (e.g. inorganic ions such as sodium, chloride, potassium etc.) are higher in the external environment than the total of these ions and other osmolytes within the organisms body fluids and cells, then the tendency will be for the latter to lose water and begin to shrink. This would be the tendency in organisms exposed to hypersaline brines as in the proposed project.

6.6.3.3 Extracellular and Intracellular Osmotic Responses

All euryhaline estuarine animals whether osmoconformers or osmoregulators show body fluid concentration changes when exposed to lowered or raised environmental salinities; it is simply the case that the concentration changes are much greater in osmoconformers. In consequence, all of these animals have to show regulation at the cellular level to minimize cell swelling or shrinkage. This process, exhibited by all cells, is known as intracellular osmoregulation and describes processes within cells that allow them to alter their intracellular osmotic pressure to match that of the body fluids, so that flow of water in or out of the cell is minimised. This relies mainly on control of the concentration of molecules that are small enough to contribute to intracellular osmotic pressure, but too large to move easily through the cell membrane. Intracellular osmoregulation is often associated with changes in the flux or metabolism of free amino acids and related organic compounds or of inorganic ions or a combination of both. In some groups of marine algae (in which osmoregulation is a rather different mechanism, involving cell turgor), complex carbohydrates e.g. mannitol may also be involved in these functions. Intracellular osmoregulation is achieved by a complex set of biochemical and physiological processes both within the cell cytoplasm and involving the permeability of the cell membrane. These transformations and fluxes are generally facilitated by a range of enzymes. The rate at which some of these processes take place may be quicker or slower depending on the compounds involved and may require more or less energy expenditure for the same reasons.

6.6.3.4 A note on Ionic Regulation

In theory, osmotic regulation may be achieved independent of the types or relative ratios of ions within the cells or body fluids contributing to the osmolality, just so long as the osmotic pressure generated is equal to that of the external environment. Usually, however, in the case of osmoconforming invertebrates, the body fluids have a chemical composition fairly similar to that of seawater, i.e. the relative contribution of all the major ions will be much the same inside as well as outside. However, the ionic composition of the body fluids in osmoregulators may differ somewhat from the external seawater. Furthermore, the internal chemical composition of cells in both osmoregulators and osmoconformers will generally tend to be different from that of the external medium (seawater). These differences will depend on the particular cells and the organisms involved. For example, ions such as K⁺ (potassium), Na⁺ (sodium), Cl⁺ (chloride), Ca⁺⁺ (calcium) and Mg⁺⁺ (magnesium) may be regulated within cells and body fluids above or below the levels in ambient seawater in both osmoregulators and osmoconformers. This fact may be particularly relevant if the proportions of these ions in the proposed brine discharge differs significantly from the proportions in ambient seawater as this may well give rise to added regulatory pressures at the level or the organism or the cell resulting in greater stress and reduced salinity tolerance.

6.6.3.5 Interstitial salinities: water density

In estuaries, as the tide ebbs and flows, the salinity in the water column increases as the tide comes in and falls as the tide goes out. The situation is rather different for the salinity of the water between the particles making up the bed of the estuary (interstitial water). Because high salinity water is more dense than low salinity water, the estuarine bed tends to 'fill up' with the highest salinity water that occurs during a tidal cycle. In consequence, the salinity of the interstitial water fluctuates far less than in the overlying water column. This phenomenon is particularly marked in the case of muddy sediments, where the fine particles reduce interaction between interstitial water and water column. Thus, it is not uncommon for interstitial waters to be at 30 psu when the overlying water column is at 5 psu. Some estuarine animals take advantage of this phenomenon. For example: the lugworm is actually a stenohaline osmoconformer - but very common in the outer/middle part of European estuaries. At low tide, when the overlying water is relatively fresh, it simply remains at the bottom of its burrow, surrounded by saline interstitial water - it only interacts with the water column when the tide comes in, bringing almost fully marine conditions. If saline brines are added to an estuary, it is probable that the interstitial environment will become hypersaline, so that animals living beneath the mud/sand surface will encounter higher than normal salinities most of the time.

6.6.4 Impacts at Islandmagee

6.6.4.1 Overview of Habitats Influenced and Invertebrate Groups Affected

The brine dispersion model predicts an inner, more or less circular area, around the pipeline diffuser where the predicted salinity will rise to greater than 2psu above ambient i.e. less than 36psu. Within this area in particular, it is likely that the bottom community will show measurable community alterations, which are likely to be more pronounced closer to the

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actual discharge point where salinity values will be greater than 40psu. The full area where salinities greater than 36psu are predicted, is contained within the biotope described during the baseline survey as, Circalittoral Mixed Sediments or Circalittoral Coarse Sediments. This biotope is characterised by a substrate of sandy gravel, gravel and pebble based on video drops, diver observation and anchor dredge samples taken in the area. The invertebrate fauna within the sediment include a diverse mix of polychaete worms, bivalve molluscs, echinoderms, and crustaceans in the main. The bottom also hosts a broad range of attached epifauna, particularly bryozoans (e.g. *Flustra* and *Alcyonidium*), barnacles (*Balanus crenatus*) and polychaete worms (*Pomatocerous*) while fish and mobile crustaceans (shrimps) were also observed in video footage using the area.

Outside the greater than 36psu area, the next interval, i.e. between 36psu and 35psu (i.e. 1psu above background), occupies a much larger area, the majority of which again coincides with Circalittoral Mixed Sediment biotope (Figure 6.6). In addition the area overlaps with small areas of other biotopes, *Echinoderms and Crustose Communities of Infralittoral Rock*, (2 areas of the latter) and a small part of *Sediment Affected or Disturbed Kelp & Seaweed Communities*. These latter communities are closer to the Islandmagee Shore in shallower waters.

6.6.4.2 Nature of the Impact and Sources of Information

Overview

In the following sections, each of the main types of organism occurring within the predicted impact zone will be assessed in terms of their known capacity to deal with salinity levels above normal oceanic levels of 33-34psu. The first section will look at reports from field studies, which have examined the impacts of hypersaline effluents on marine invertebrate communities living in seabed sediments. The second part of the section will deal with what is known from the published scientific literature about how each main class of invertebrate occurring in Islandmagee can cope with above normal salinity. In each case, the implications of these reviews for the Islandmagee project are also presented.

Findings from Field Studies on Hypersaline Discharges to the Marine Environment

Our knowledge of the impact of increased salinity on the benthic infauna communities and marine communities in general comes almost exclusively from research undertaken on the impact of brine discharges from desalination plants, principally from the Gulf States and the Mediterranean. Publications on the impact of brine discharged from lixiviation of gas storage caverns (i.e. what is proposed at Islandmagee) are extremely scarce, and what is available is incomplete. A shortcoming in using data from desalination studies is that desalination brine also contains chemicals other than salt e.g. descaling agents and biocides among others. Moreover, data from the Gulf area in particular would have limited relevance for the types of marine community found off Islandmagee. Nevertheless, the limited data, mainly from the Mediterranean, helps to shed light of what trends might be expected at a community level in Islandmagee.

Some Trends In Community Structure from Field Investigations - Desalination Studies

In a study of the impact of a desalination brine discharge off Alicante in Spain, (Del Pilar Ruso *et. al.*, 2007), where salinity was at or above 39-40.6psu, the bottom soft sediment community changed from one dominated by Polychaeta, Crustacea and Mollusca to one dominated by nematodes (up to 98%). The background salinity in this area was around 37.9psu. Thus there was a reduction both in terms of abundance and diversity of several groups attributed to the increase in ambient salinity. The volume of the discharge was $2.7 \times 10^3 \, \text{m}^3/\text{hr}$ at $68 \, \text{psu}$.

In a similar study (Del Pilar Ruso *et al.*, 2009), where the benthic infauna was studied for one year before and for 2 years after the commencement of a desalination brine discharge (3.3x10³ rising to 6.7x10³ m³/hr at 70-90psu), at stations where the salinity rose by about 1.5 to 3% above the previous background level, there was a reduction in the richness and abundance of several families of polychaete worms, with some disappearing after the first year and others taking two years to disappear. In contrast, two more salinity tolerant families increased in abundance at the impacted sites. The substrate at the impacted sites comprised a mixture of mud, coarse, medium and fine sand and gravel. The area wasn't very hydrodynamic.

The impact of a much smaller desalination discharge off the Italian coast (Castriota *et. al.*, 2001), noted that close to the discharge, numbers of all benthic invertebrates decreased and that crustaceans, echinoderms and molluscs nearly disappeared. Pre-discharge salinities at the most affected station ranged from 36.9 to 37.9, while after the commencement of the discharge they rose to 47.4- 49.6 at the affected site. The impact was not discernible at a very short distance from the discharge due to rapid mixing.

Finally, another paper working in the same study area as the first study referred to above noted a decline in echinoderms in seagrass meadows close to a desalination plant discharge off Alicante (Fernandez-Torquemada *et al.*, 2005). However, the paper doesn't provide sufficient detail to allow the aerial extent of this impact to be assessed.

Another study off the coat of Spain in the NW Mediterranean, (Raventos *et al.*, 2006), failed to establish a statistically significant link between a desalination plant brine discharge (discharging around 28% of the projected maximum salt load proposed at Islandmagee) and changes in the benthic community monitored for a full year before and after commencement of the discharge. The surveys were monthly for 24 months by diver observation combined with simplified bottom sampling for hermit crabs. The study concluded that the magnitude of natural variations within the community masked any impact from the brine discharge. Other confounding factors were considered to be the rapid dilution of the brine and the highly hydrodynamic nature of the system. They further noted that the many of species being censused by the divers were mobile (e.g. 15 species of fish). They also suggest that because the area affected by the discharge is so small, (i.e. 3500m² – 59m x 59m) that this may also be a reason that an effect couldn't be discerned. Unfortunately no ambient salinities are reported in this paper.

Overview of Desalination Plant Impact Studies

Several of the study areas mentioned in these extracts are influenced by other community stressors, in particular sewage discharges. Some also occur in areas of poor hydrodynamic mixing, shallower tidal ranges and in general, finer sediment than at the Islandmagee site. Despite these limitations however, when taken together, these papers give us some insights as to how benthic communities might be expected to react to point source saline discharges.

The most pronounced impacts are noticeable at sites close to discharges although there is some suggestion that they may be farther afield in areas with larger discharges and poorer hydrodynamics.

When studies are undertaken for more than one year from the commencement of a discharge, then the impact becomes more pronounced in subsequent years of discharge. Significant impacts (in terms of community change) are detectable at salinity increases of around 2psu above background and become most pronounced with higher elevations. It may be difficult to demonstrate impacts in areas with highly hydrodynamic environments, especially among mobile, ⁴epibenthic animals (e.g. fish and perhaps some crustaceans). If the area of impact is small, then it may also be difficult to demonstrate impact, although this feature may only apply to mobile epibenthos rather than to infauna or attached epibenthos e.g. bryozoa and hydroids.

6.6.4.3 Sensitivity of Individual Species and Groups of Invertebrates to Increased Salinity

In this section published studies on the salinity tolerance and osmoregulatory mechanisms of some of the invertebrate groups noted in the site surveys and others which occur in the Islandmagee study area will is reviewed in order to broadly assess their potential vulnerability to the proposed discharge. Unfortunately, many of these studies examine species capacities to tolerate low or fluctuating salinities, rather than higher salinities, which are rarer in nature. Nevertheless, some of these studies have extended their salinity testing into a higher salinity range giving some insights into the likely course of hypersaline impacts. Furthermore, an organism's ability to cope with lower salinity can shed light on how they may adjust to higher salinities. These various data sources have been used to predict the nature and scale of impacts we can expect within the study area.

Echinoderms (Starfish, Brittle Stars, Sea Urchins and Sea Cucumbers)

The most widespread echinoderms within the study area are the brittle stars *Ophiothrix* fragilis, and *Ophiocomina nigra*, particularly at intermediate depths and areas of strong tidal currents, whereas in deeper water over gravel and sandy gravel, other brittle stars are present but at much lower densities. The common star fish *Asterias rubens* and the sun star *Solaster papposus* are frequently encountered, along with several other starfish species and brittle stars. The common sea urchin (*Echinus esculenta*) is prominent in the shallow subtidal area of kelp and red seaweed communities where it is an important herbivore and general grazer, while in deeper water over gravel, other species e.g. *Psammechinus miliaris* may be present – the common heart urchin (⁵*Echinocardium cordatum*), although common in

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⁴ Epibenthic refers to animals, which live on top of rather than within the bottom sediments - they maybe mobile e.g. shrimps and fish or sessile e.g. keel worms, hydroids and barnacles.

⁵ Echinocardium cordatum is also known as the Sea Potato

suitable substrates around the British Isles is probably not present in the study area because the sediment is generally too coarse. However, the small interstitial dwelling species *Echinocyamus pussilus* was frequently encountered in dredges at the deeper sampling sites.

The general consensus in the scientific literature is that echinoderms do not osmoregulate and are particularly stenohaline as a group. Within the group, it is clear that certain species have a wider range of tolerance and according to Stickle and Diehl (1987) brittle stars (Ophuroidea) are the most euryhaline class within the group.

Sea Urchins

In experimental research on the survival of larval stages of the heart urchin Echinocardium cordatum in a range of temperatures and salinities, (Kashenko 2007), successful fertilization was observed in the temperature range 8-22 °C and salinity of 26-36psu with the largest proportions of surviving larvae (84% - 97.8%) occurring in conditions of 17-20°C and salinity ranges of 28-34psu. Depending on temperature, from 14 to 30% of larvae released from the egg capsule were abnormal at 36psu compared to 6 to 18% at 34psu. When surviving normal larvae were tested at later stages of larval development against the same range of temperature (12-22°C) and salinity (20-36psu), it was evident that some stages survived better at the higher salinity (36psu) than others, over the 4-day test period. 100% of all blastulae (first post egg-stage larva) survived at the highest test salinity 36psu at all temperatures, whereas the following stage (pluteus I) had lower survival at 34psu and 36psu at 17-22°C (~70-90%), dropping to 60-68% at 12°C and ~30-45% at 25°C for the same salinities respectively. The later stages of larval development saw 100% survival of larvae in 36psu within the tested temperature range; higher salinities were not tested. test adults were taken from Vostok Bay (Russia) in salinities of 32.6-33.2 psu. The increase in salinity tolerance range of larvae as they mature is a feature common to other echinoderms also (see Hendler 1997 quoted in Stickle and Diehl (1987)

Pétinay et. al. (2009) working in France investigated the optimum rearing conditions for larvae of the purple sea urchin (Parcentrotus lividus), a species which commonly occurs around Britain and Ireland in suitable habitats. They were trying to determine the optimum conditions for producing normal larvae for bioassay tests. They demonstrated that the optimum salinity range for healthy larvae, during a 4-day experimental period, was 28.8 -32.7psu, in 18-20°C. Above and below these salinities, the percentage of larvae either not developing or resulting in malformed larvae increased e.g. 5, 22, 78 and 100% of larvae failed to develop at 36.6, 38.6, 40.5, 41.9 psu respectively, and in addition, 15, 20 and 34% larvae developed abnormally at 34.7, 36.6 and 38.6 psu respectively. Adults supplying the eggs and sperm had been raised in 33psu artificial seawater. Research on the same urchin undertaken by Quintino et al., (2008), indicates somewhat higher tolerance. experiments, carried out in Portugal, approximately 4% and 10% of urchin larvae developed abnormally at 36 and 40psu respectively, while this figure increased sharply to ~70% at 45psu. The same research only showed significant fertilization failure in the same species first at 45psu (i.e. ~20%). These tests were carried out over 3 days and at 15°C. No obvious reason for the apparent discrepancies between the French and Portuguese studies can be suggested, but it is notable, that the French results are closer to those of the Russian study on Echinocardium (Kashenko, 2007).

In an early Scandinavian paper, Lindahl and Runnström (1929) quoted in Gezelius (1963), stated that the salinity range of eggs of another sea urchin, *Psammechinus miliaris*, a species likely to be present in the Circalittoral Mixed sediment in the brine plume mixing zone in Islandmagee, do not differ by more than 6-7psu from the salinity in which the sea urchins live – a proposition partly supported by Gezelius (1963) who demonstrate a salinity range of 24-38/40 psu for *Psammechinus miliaris*, at 13°C, although the optimum was 32psu.

Information on the salinity tolerance of the small interstitial urchin *Echinocyamus pussilus*, has not been obtained and although it occurs in waters ranging from 22psu in the Baltic to 39psu in the Mediterranean (Richter, and Bruckschen,1998), the species' small size and habit of living burrowed in the sediment may, nevertheless, increase its vulnerability to salinity stress in the high salinity zone around the proposed Islandmagee discharge.

Starfish

The salinity tolerance of adults and larvae of Common Starfish (*Asterias rubens*) from the Barentz Sea (ambient salinity 32-34psu) are given by Saranchova and Flyachinskaya (2001) as follows: fertilized eggs (34psu), gastrula-stage larvae (32-34psu) bipinnaria-stage larvae (20-38psu) and adults (20-40psuThe adult range is not based on mortality but on reduced feeding activity over 3 days in test salinities, for the larval stages the test end-point was determined by mortality. In a salinity choice test in the same study, adult starfish most often chose the salinity range 32.5-35psu. Thus the salinity tolerance (high and low end) increases with successive stages in the development of the larvae and is highest in the adult and lowest in the fertilized egg, which appears to have effectively no tolerance of salinity fluctuations. The latter was borne out by similar research on the same species, albeit from a low salinity adapted population in the White Sea (Sarantchova, 2001), which showed that successful fertilization occurred within a 2psu salinity range, with non-fertilizations increasing progressively as salinity increased or decreased outside this range.

Sub-lethal Effects

Echinoderms are known to drop their normal activity rates (e.g. burrowing rate) at salinities outside their optima, while feeding rates of starfish are reduced in sub-optimal salinities (Yamaguchi 1974 in Stickle and Diehl, 1987). At salinities above their tolerance range, oxygen consumption in some echinoderms is known to decrease (Giese and Farmanfarmaian, 1963 in Stickle and Diehl, 1987).

6.6.4.4 Implications for Echinoderms of the Islandmagee Brine Discharge

Apart from the possibility of avoidance by or mortality of echinoderms within the inner zone of >40psu salinity, a combination of reduced activity, feeding and growth in areas of sub-optimal salinity (in this case high salinity) could contribute to poor growth and reduced reproductive output in individuals at the edge of the impact area (38-40 psu). This coupled with reduced survival rates of fertilized eggs or early stage larvae and reduced survival in benthic stages which settle in areas of high salinity, may result in reduced recruitment of some or all echinoderms within the area of salinities above 36psu and especially above 40psu.

Molluscs

Bivalves

The area surrounding the proposed outfall has a diverse range of bivalve molluscs living within the sediments, most if not all of which maybe stenohaline, i.e. normally only exposed to a very narrow range of salinity fluctuation. In general, bivalves have been shown to be osmoconformers, i.e. the osmotic strength of their body fluids follows closely that of the external medium (i.e. seawater). The vast majority of work undertaken on the ability of bivalves to adapt to altered salinity concerns species exposed to reduced salinity, particularly reduced salinities in the context of estuaries, where certain species will be exposed to tidally induced and therefore rhythmic changes in salinity (i.e. osmolality). Thus, while little published data is available to us with regard to how these molluscs deal with hypersaline conditions (i.e. above oceanic salinity levels), how they cope with hyposaline conditions (i.e. concentrations below oceanic salinity) may give us some clues, as to how they may cope in the former.

Bivalves can detect the external salinity and when it is unfavourable (in most cases studied this means when it is falling) it reacts in a number of ways behaviourally in order to protect the internal body fluids from the changed external environment, the most common being shell closure. This works well for species such as mussels (Mytilus edulis), which can seal their shells completely; whereas for species such as queen scallop (Chlamys opercularis), the seal is poor, so its effectiveness is very limited (Shumway, 1977). On the other, the latter species and its relative the king scallop (Pecten maximus) have the ability to 'swim' by rapid closing of the gaping valves and this may allow adults especially to avoid areas of increased salinity. The majority of bivalves, however, are either attached by byssus threads e.g. mussels and saddle oysters (Anomiidae sp) or most frequently, as in Islandmagee, buried in sediment, thereby preventing them escaping from unfavourable conditions by swimming.

Bivalves that close their shells metabolise anaerobically, which potentially leads to the build-up of organic acids and acidosis, which is buffered by calcium carbonate / bicarbonate chemistry. This buffering has been noted for both short (several hours) and long (several days) periods of valve closure (see Burton 1983). This mechanism may be useful for Islandmagee bivalves to cope with external salinity stress during temporary elevations in ambient salinity associated with tidally induced shifts in the extent of the discharge plume. However, over extended periods resorting to such survival mechanisms may prove unsustainable energetically, leading to poor growth and reduced reproductive output.

Published data on the salinity tolerance of bivalve larval stages is quite limited. However, available data points to generally higher sensitivities than adults. Research on the blue mussels (*Mytilus edulis*) of the White Sea (ambient salinity 24-26psu) Saranchova & Flyachinskaya (2001) showed that the test animals exhibited increased range of salinity tolerance with each successive developmental stage as follows: fertilized egg < embryos < early larva < late larvae. In this sequence it was noted that the optimum salinity range for egg fertilization was very narrow range (22-26psu) and at salinities just above and below, the percentage of normal fertilized eggs dropped off rapidly. However, at the veliger stage, when larvae grow a small shell, the salinity tolerance range widened considerably such that all test

animals survived for 14 days in the range 10-40psu. We can postulate, therefore, that mussels raised in areas with full oceanic salinity will have a salinity tolerance at early development stages (i.e. fertilization) in and around the salinity of their area i.e. in Islandmagee of say 32-35 psu. Moreover this range would be expected to expand to an upper salinity limit of 40psu, perhaps higher, by the late larval stages. The veliger stage is common to all bivalve larvae and may therefore confer the same additional tolerance at this stage in development to other bivalve molluscs also. However, the blue mussel is a euryhaline bivalve and not a prominent species in the Islandmagee area, where bivalves such as the scallop Pecten maximus and several other species of bivalves occur, which are normally exposed to much narrower salinity ranges and are, in the main, therefore likely to be much less euryhaline and more stenohaline. Davenport et al., (1975) noted that veliger larvae of the king scallop (Pecten maximus), seem to be less tolerant that mussels, with mortality of about 25% after 24hrs at 40psu at 10°C, a rate which rises as temperature increases. Modiolus modiolus, the horse mussel, was present in small numbers at most of the Islandmagee dredge stations; it has a reported salinity range of 26-41psu (Pierce, 1970) quoted Marine SAC online in UK resource (http://www.ukmarinesac.org.uk/communities/biogenic-reefs/br3 3.htm)

While Paul (1980) indicates that larger queen scallop (*Chlamys opercularis*) have lower salinity tolerance than smaller specimens of the same species (in that case to reduced salinity), Chanley 1973 (quoted in Paul, 1980) states that smaller bivalves succumb more rapidly to lethal salinities. In general, this latter observation is likely to be more representative of most groups, not just bivalves.

In the Islandmagee study area, increased adult mortalities, poor growth rates and reduced reproductive output of all bivalve species, with perhaps elimination of some more sensitive species, is anticipated at salinities greater than 40 psu. This area may be abandoned by more mobile species such as scallops (*Pecten* and *Aquipecten*). In addition, late larval stages settling in this zone from the plankton are also likely to experience increased rates of mortality. In the zone of 36-40psu, a shift in the community composition can be anticipated, particularly at the inner higher salinity area (38-40psu) with certain species, becoming scarcer. Nevertheless, the salinity extremes here are lower, and bivalve closure in response to semi-diurnal tidal movements of the plume may be sufficient to allow populations to remain in this area, even if their conditions are sub-optimal. Larval settlement in this area is also likely to be at higher risk of mortality than in background areas.

Below 36psu, no adverse impact is anticipated for adults of juveniles of this group and settling larvae would only be at marginally greater risk of mortality if at all, than in unaffected areas.

Salinity stress on bivalve predators, especially starfish, in the higher salinity zone around the diffuser (>40psu) may give a slightly higher survival rate to bivalve populations, which can survive the salinity stress, although this cannot be proven, without experimentation.

Other Molluscs

A few species of marine snail (Gastropoda) were noted at stations within the Circalittoral sediments around the outfall and within the areas of most elevated salinities predicted by the dispersion model. This group, like the bivalves are osmoconforming species, whose body fluids more or less reflect the same osmotic and ionic strength and composition as the ambient seawater. Published salinity tolerance of this group for species within the study area appears to be confined mainly to the intertidal periwinkles (Littorinids). These species, including Melarhaphe neritoides, Littorina saxatilis, L. litorea and L. obtusata can tolerate salinities as high as ~45psu for several days (Avens and Sleigh, 1965). In addition, several intertidal molluscs, which have the ability to retract into their shells shielding themselves with their opercula during adverse external conditions, may increase the ionic concentration of their internal fluids due to desiccation to a much higher level than seawater and still recover when again exposed to normal conditions after more than one week (Avens and Sleigh, 1965). It also seems that the farther up the shore a snail normally occurs the more tolerant it is to fluctuating salinities and water loss, whereas species normally on the mid to lower shore e.g. Nucella lapillus, Gibbula cineraria are less so. Nevertheless, the dispersion model predicts that the entire intertidal area will not experience salinity concentrations more than 0.5psu above normal background levels. Furthermore, the fact that much of the nearshore area only marginally affected by the discharge, means that eggs and larvae released into the plankton by littoral gastropods and other intertidal species, will have a higher chance of being unaffected entirely. Littorina saxatilis (the rough winkle), which lacks a planktonic stage, giving birth to shelled juveniles, should be at no risk from this source.

A few species of chiton (Polyplacophora) occurred frequently in the anchor dredge samples taken from the gravel sediment around the outfall area. These species are osmoconforming species, whose body fluids rapidly come to osmotic equilibrium with the external environment, they may be more susceptible than bivalve molluscs to sudden salinity stress as they don't have the possibility of full shell closure.

Crustaceans

Crustaceans are a very diverse and successful group of marine invertebrates, which have developed osmoregulatory capabilities that allowed some species to penetrate estuarine waters and freshwaters. Several very euryhaline species can straddle the whole range from full seawater to freshwater at different stages in their life cycle. The high economic importance of many crustaceans especially decapods including, shrimps, prawns, crabs and lobsters, coupled with the wide range of salinity tolerance of some members of the group has meant that considerable research has been undertaken on their osmoregulatory mechanisms, especially at the juvenile and adult stages. In more recent times, increased data is also becoming available for the various larval stages and to a much lesser extent the egg / embryonic stages also.

Many crustaceans have the ability to alter the osmotic strength of their body fluids but the extent to which this will occur will vary depending on the species and the life stage. Furthermore, the salinity tolerance of a given species generally reflects the degree of ambient salinity variation they are normally exposed to, such that stenohaline species, occurring in fully marine environments tend to have a lower salinity tolerance range. For

example, the larvae of the stenohaline marine species ⁶*Hyas araneus* (a large spider crab) displayed conspicuous stress affects when salinity was reduced from 32 to 25psu, while the same was not true of the more euryhaline shore crab (⁷*Carcinus maenas*) (Anger, 1985 in Anger 2003).

Osmotic regulation in euryhaline crustaceans is maintained by the use of ion pumps, which control the flux of Na^+ and Cl^- in particular, although K^+ , Ca^{++} , Mg^{++} and SO_4^- are also regulated to varying degrees. The site of the main osmoregulatory tissue in metamorphosed larvae, juveniles and adults in decapods crustaceans (crabs, lobster and shrimp) tend to be the gills, gill cavity and associated appendages. In low salinities the tendency is to maintain the body fluids (e.g. haemolymph) somewhat above that of the external environment, while in elevated salinities the tendency is be to maintain a similar osmotic strength to the external medium.

Surveys undertaken for this study indicate a diverse crustacean fauna off the Islandmagee east coast. Species observed during dive and video surveys were mainly decapods and include velvet swimming crab (Necora puber), European lobster (Homarus gammarus), brown or edible crab (Cancer pagurus), rugose squat lobster (Munida rugosa) and various species of shrimp. The dredge samples also recovered a diverse range of smaller species living in and on the gravels and sandy gravels in deeper water (both decapods and other groups). It is likely that the bulk of these species are stenohaline or at most weakly euryhaline and therefore that their salinity tolerance and osmoregulatory capacity will be relatively narrow, i.e. the majority would be confined to near fully marine waters with little penetration into estuaries. Some however, like the barnacle Balanus crenatus, which were very frequently encountered attached to larger pebbles and stones in the deeper anchor dredge sites, are described as euryhaline. Davenport, J (1976). In experiments, adults were still active in salinities as low as 14psu after acclimation (Anderson, 1994) and larvae of the species are known to be able to survive for short periods in salinity ranging from 20psu-40psu (Barnes and Barnes, 1974). This species should be able therefore to tolerate salinities of at least 40psu, possibly more. Like other acorn barnacles, it can close its operculum during periods of adverse environmental conditions, which should assist it in dealing with fluctuating high salinity better.

Lobster can survive in areas of moderately reduced salinity and they also occur in the wild in parts of the Mediterranean where the ambient salinity is 36-38psu (Pavičić-Mamer et al, 2003). Moreover, in laboratory tests 1-yr-old juvenile lobster, survived with little or no mortality between salinities of 13.6 and 47.6psu (Charmantier *et al*, 1984). The latter were short-term tests lasting perhaps only a few days and under laboratory conditions, so one would need to be cautious in extrapolating these figures to the wild and for longer periods.

The development of fully functioning juvenile and adult osmoregulation in many decapod crustaceans occurs in stages during post-embryonic larval development stage. In lobster, larval stages I-III are osmoconformers, while the later stages (IV and V) after metamorphosis

⁶ This species is widespread in suitable habitats around the British and Irish coastline.

⁷ Also known as green crab by fishermen

can weakly osmoregulate, which is complete with the development of the juvenile after settlement of stage V. (Charmantier *et al.*, 2001). It has been noted in the case of the American lobster (*Homarus americanus*) that the eggs, which cannot osmoregulate, are protected by a relatively impermeable outer membrane (Charmantier and Aiken, 1987 cited in Charmantier 1998).

Increasing osmoregulatory regulation and associated salinity tolerance with successive larval development has also been demonstrated in the more euryhaline shore crab Carcinus maenas. (Cieluch et al., 2004). It is likely that a similar process occurs in most if not all the shrimps and crab species within the study area, although the tolerance ranges will tend to be smaller in these species, as most are likely to be stenohaline osmoconformers. In general, the early larval stages tend to be less tolerant of salinity stress than the later and adult stages, although there are exceptions. Wanson et al., (1983), demonstrated that young Cancer pagurus (average carapace width 7cm) collected in the lower rocky intertidal had a high survivorship after direct transfer from fully saline to 50% seawater for 15 days, whereas larger specimens (14cm average carapace width) caught offshore, experienced 50% mortality after 24hrs. Investigators, while demonstrating that the young crabs reduced their tissue levels of free amino acids during acclimation to reduced salinity, attribute their tolerance in the main to their ability to withstand increased tissue volumes following higher water intake in dilute seawater. How this species would cope with high salinity conditions isn't known but a mixture of weak extracellular and intracellular osmoregulation combined with tolerance of limited tissue shrinkage are likely to be necessary. Harris and Bayliss (1988) detected only very low levels of the osmoregulatory enzyme Na⁺ / K⁺-ATPase in this species, but also noted that some activity could be induced after acclimation to low salinities and perhaps the same may operate in higher salinities. Adults of two other Cancer species (C. irroratus and C. borealis - Atlantic North American species) are known to be able to withstand upper limit salinities of 44psu as adults, after acclimation, a day at a time, to the higher salinity, in 10% (3.5psu) increment steps. Salinities above 44psu proved fatal and the ⁸LC50 was 65psu for both species. The authors (Charmatier and Charmantier-Daures, 1991) do not indicate for how long these tests were conducted, but they are believed to be short-term acute tests, probably lasting only a few days.

Salinity tolerance in other decapod species

Choy, (1991) researching the early development of two common crab species around the British Isles (*Liocarcinus holsatus* – flying crab and *Necora puber*- velvet swimming crab), showed that unfed early hatched larvae (zoea), could survive for up to 15 days in the salinity range 30-45psu at a temperature of 15°C. Median survival was best at 35psu and overall was better at higher rather than at lower salinities (range tested 10-50psu). For *L. holsatus* best survival at lower temperatures (5-12°C) were at ~30psu, whereas at higher temperatures (17 and 22 °C), salinities of 35-45psu gave the best survival rates.

Recent research on adult velvet swimming crab (*N. puber*) (Al⁻Azhary *et al*, 2008) points to changes in blood (haemolymph) chemistry in adults exposed to salinities of 40, 45, 50, 55

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⁸ LC50 is the concentration in which 50% of test animals died.

and 60 psu compared to controls kept at 35psu. Exposure at each test salinity lasted for 4 days. Most major ions increased with increasing salinity but only in the case of magnesium, at all salinities, and potassium at the two highest, was this increase relatively higher than the rate of increase in the medium. Most parameters showed the greatest divergence at the highest test salinities (55 and 60psu), which was especially obvious in the case of pH (reduced) and ammonia, total protein and glucose (all increased). The authors point to the potential negative consequences of these changes for impacted animals e.g. increased oxygen consumption (i.e. inefficient energy use with potential for adverse knock-on impacts on growth and reproductive capacity), direct toxicity from accumulated ammonia, reduced locomotory activity due to a build up of Mg2⁺ and poor performance of certain enzymes due to ionic imbalance. It isn't clear, however, whether the relatively minor changes observed at 40psu would have any significance for survival and growth in this species.

Summary of Osmotic Stress Impacts in Crustaceans

According to Anger (2003) osmotic stress occurs when the average level or extent of variability exceeds certain limits, which differs among species and development stages. He also notes, that in the case of crustaceans, that the effects of salinity stress have been observed in reduced survival, feeding and growth rates, as well as extended or suspended moulting cycles, metabolic shifts in energy partitioning, and in altered behaviour. Moreover, these effects may be compounded by synergism with other factors e.g. temperature. Even a slight delay in larval development may reduce the chance of survival in the plankton because of prolonged exposure risk of predation, starvation and physical stress (Anger, 2003). In the case of temperature, it is normally very cold temperatures when combined with salinity stress that usually prove more problematic that increased temperatures.

Implications of Proposed Brine Discharge on Crustaceans

The greatest numbers of crustaceans within the study area are those small-bodied species present in and on the sediments around the outfall. Without sufficient information to the contrary, we must assume that these species are in the main stenohaline osmoconformers with limited capacity for extracellular osmoregulation. That said, there is sufficient data in the literature to indicate that both adults and larvae of several species within the study area in general, including, lobster and velvet swimming crab, can cope with salinities at least up to 40-45psu for limited periods, offering the prospect that others, e.g. the euryhaline barnacle, Balanus crenatus, may be able to cope at these levels also. In most instances, these tolerance levels are based on static laboratory tests, i.e. they do not take account of the fact that in the field, salinity will fluctuate at any given point within the mixing zone, so that the internal fluids may equilibrate at a lower level that the maximum experienced in the external environment. This latter effect will be less pronounced in smaller-bodied species, which can be expected to equilibrate faster than the larger species.

In the inner zone, closest the outfall diffuser, where salinities above 40psu will occur, it is possible that there will be a significant reduction in both the diversity and biomass of crustaceans, especially small species, either through emigration or through gradual mortality as the discharge ramps up. Potentially tolerant species, e.g. barnacles, may survive within this high salinity zone, possibly without reproducing, or with slower growth rates. Furthermore, these effects are more likely to be observed in the second and subsequent

years as cumulative stress takes a toll on internal reserves of individuals coupled, with poor survival rates of newly settled recruits within this inner zone. There may also be a seasonal affect with a lower diversity and biomass occurring during the coldest months, when the synergetic affect of low temperature and elevated salinity exert a greater impact. In the surrounding areas i.e. in the zone between 36 and 40psu, this effect will probably be difficult to detect in most species and between 34 and 36 psu, no impact is likely to be discernible.

It is important to note brine discharges will take a full year of gradual discharge volume increase to reach a plateau. This should allow many species to gradually acclimate, at least is areas of moderate average salinity increase, if not in the areas of highest predicted increase. In areas where the increase is outside the species tolerance range even after acclimation, then mobile species such as many crustaceans may avoid these areas.

Polychaetes

Marine polychaete worms (also known as bristle worms) are a very diverse group, often the most species rich component of the benthic community in sediment substrates of all grades from mud, through sand to gravel. The distribution found at Islandmagee is no different, with polychaetes comprising the most species rich group at all the anchor-dredge (gravel) sites. The majority of these species are likely to be stenohaline, and osmoconformers, occurring as they do in conditions of full salinity.

Polychaetes are generally confined to marine waters although very many species have also evolved to penetrate far into estuaries and these are more or less euryhaline. Much of the detailed work on osmoregulatory behaviour and physiology has been undertaken on common euryhaline species such as *Nereis virens* or *Hediste diversicolor*, with more stenohaline species less studied.

When euryhaline polychaetes are experimentally transferred to dilute seawater, they rapidly increase in weight over a short time period of a few hours (Fewou and Dhainaut-Courtois, 1995) and gradually, the original volume is approached, although not fully achieved after a longer period of at least two days. Quinn and Bashor (1982) have shown that Nereid polychaets are osmoconformers until the salinity drops to about 30% of normal seawater at which stage they begin to maintain body fluids at omolarities higher than the external medium. The excretory organs of polychaetes (the nephridia) are believed to play a part in salt and water control (Barnes, 1968) In addition to extracellular volume regulation, polychaetes, like all osmoconforming invertebrates, rely also on intracellular mechanisms both for osmotic regulation and volume control. For example in the red blood cells (coelomocytes) of the polychaete Glycera (Costa et al., 1980), a combination of inorganic ions (K⁺, Ca⁺⁺, Mg⁺⁺) and free amino acids are thought to play roles in this process. As a general rule, we can expect a similar combination of mechanisms to play a role in osmotic control when polychaetes are exposed to hypersaline conditions, with stenohaline species (probably the majority at the Islandmagee sites), having a narrower tolerance range than euryhaline species. This is borne out by Lyster (1965) who demonstrated that in several tested species of polychaete, the degree of tolerance to hyposaline (dilute) solutions was a good predictor of the same species hypersaline tolerance.

As in the case of the majority of invertebrates reviewed, the larval stages of polychaetes have a narrower range of salinity tolerance than adults, and earlier larvae may be more sensitive than later larval stages in development (Ushakova and Sarantchova, 2004), although this doesn't hold universally, as some intermediate larval stages may be more tolerant than later ones (Qia and Qian, 1997). Knowledge of the salinity tolerance of polychaetes occurring in the Islandmagee area is very limited, especially their tolerance to elevated salinities. Work by Lyster (1965) notes that the keel worm (*Pomatoceros triqueter*), commonly encountered in Islandmagee dredge samples, which can penetrate estuaries in the region of 18-23 psu, and *Scolopus armiger*, which can also penetrate to areas as low as 17psu, can both also tolerate a degree of hypersalinity. While two other species, *Phyllodoce maculata* and *Notomastus* (sp.) are less tolerant. Lyster speculates that the calcareous tube of *Pomatoceros* may provide it with some protection against salinity stress.

Sensitivity of another Islandmagee genus, *Sabellaria* (*S. alveolata*) is known to be high at the larval stage, with 20% and 70% of larvae developing abnormally in test solutions of 36 and 40psu respectively, suggesting poor survival to maturity in this species at elevated salinities i.e. >40-45psu (Quintino *et. al.*, 2008). A study assessing the impact of a desalination discharge on soft sediment benthos in the western Mediterranean (Del-Pilar-Ruso et al., 2007), highlights the sensitivity of the adults of several polychaete families to hypersaline conditions as follows: Sabellidae, which appeared to be the most sensitive family, followed by Cirratulidae, Syllidae and Onuphidae, which took longer to disappear completely (~2 years), followed by Nephytidae, Eunicidae and Capellidae, which did not disappear but decreased in abundance, while Paranoidae and Magelonidae, were the most resistant to salinity increase. The most impacted stations in that study had ambient salinities ranging from 38.5-40psu. Several of these families **are** represented among the greater than one hundred species of polychaete recorded in anchor dredge and grab samples in the Islandmagee study area (see Section 6.5 "Sediment Infaunal Survey".).

It is a feature of estuarine sediments (mainly muds and muddy sands) that salinities tend to be higher and more constant within these sediments than in the overlying waters, which may fluctuate widely during each tidal cycle (see Davenport, 1985). A similar trend may pertain at the deeper sedimentary stations around the proposed outfall at Islandmagee, although the affect is likely to be less pronounced because the coarseness of the material will likely facilitate faster exchange with the overlying water. Nevertheless, the deeper layers of sediment may experience on average higher and more constant salinities than those of the overlying water, and this may in turn have a more pronounced adverse impact on burrowing species, e.g. polychaetes in the higher salinity zone (>40psu).

Taking these data together it is probable that the inner higher salinity zone >38 psu predicted by the initial dilution prediction model (shown as less than 10m from the point of discharge in Figure 9.20 on page 9-25 of Chapter 9) will see a significant reduction in the diversity and abundance of polychaetes in general with certain families either disappearing entirely or becoming much less species rich and less abundant. Furthermore, reproductive success of polychaetes within this zone, as well as the survival of larvae developing or settling within the zone is likely to be reduced. This affect might also be detectable among the more sensitive families in the area covered by 36-38psu salinity contours, but the affect should be far less

pronounced here. Below 36psu these affects are unlikely to be distinguishable above the normal variability in benthic communities.

Other Phyla and Groups

Sponges, Cnidarians, Bryozoans, Ascidians

Compared to echinoderms, molluscs and crustaceans comparatively little has been written about the osmoregulatory capacity of the 'lower phyla'. These groups have comparatively simple bodies, without properly differentiated and separate internal body cavities where it would be possible to maintain an osmotic environment different from the exterior. As such, all these groups are believed to be osmoconformers, without the ability to osmoregulate. While a number of species in these groups are known to be euryhaline, the majority are likely to be stenohaline. Sponges such as Hymeniacidon and Halichondria can penetrate into estuaries, as can several sea anemones such as the intertidal *Actinia equina* (beadlet anemone) and the lower-shore and sub-tidal *Metridium senile* (plumose anemone). A widespread solitary Ascidian (*Ciona intestinalis*) seems to have broad salinity range with normal embryonic development being reported from Scandanavia at salinities as low as 12-18psu and in Spain at 34.4psu (Bellas, 2003), while normal larvae were hatched in salinities between 32psu and 42psu in the laboratory (Bellas, 2003) where the parent population were collected from the wild where the average salinity is 34.4psu.

A feature of these groups generally is that they live lives attached to stones, rocks and seaweeds and thus cannot escape their immediate environment. Moreover, their lack of external skeleton, shells, or extra body cavities and the fact that many continuously filter feed passing water through their bodies e.g. sponges and ascidians (sea squirts) means that they are particularly vulnerable to the impacts of brine. Those species that have been studied have been shown to use intracellular osmotic regulation based on altering levels of free amino acids and related organic osmolytes to adjust their internal osmotic pressure, and a degree of volume regulation has also been noted (Deaton et al., 1988). The species studied are in the main euryhaline, and these would be expected to have more developed intracellular control mechanisms, perhaps combined with other measurements e.g. involving the permeability of the integument. Stenohaline species in contrast may not have well developed systems or if they can be induced, they may be more energy inefficient and therefore less sustainable over an extended period. For all of these reasons, it is likely that these groups will suffer a greater level of impact than others. This view is confirmed by the results of monitoring of a brine discharge site at Aldbrough on the North Sea coast of England, where video surveys have noted a 'reduced diversity close to the diffuser' (Minutes of the Aldbrough Gas Storage Project Ecological Monitoring Committee April 10th 2008). Again, because of their static and exposed habit, these communities are easier than most to monitor, while other groups, equally as impacted may not be as easily assessed in a high energy, unstable environment.

6.6.4.5 Impacts on Algae at Islandmagee

The extreme low shore areas at Islandmagee, exposed only during low spring tides down to around 8-15m are dominated by brown and red seaweeds. Perhaps the most important being kelp species, in particular *Laminaria hyperborea*, which forms dense beds in places.

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These are important because they provide points of attachment for other seaweed especially reds and for filter feeding animals e.g. ascidians, bryozoans, hydroids, etc. along their stipes (stalks). Also, their holdfasts, where they attach to the substrate often have a diverse community of worms, bivalves and a range of encrusting animals and red seaweeds. They therefore enhance local biodiversity and density (due to their structural nature). In addition, depending on their density, the shade cast by these large plants heavily influence the light climate below them (in the same way as a forest canopy does in terrestrial habitats) and hence what plants will grow there. Furthermore, kelp and their associated red algal epiphytes, as large primary producers, provide an important food source for a range of herbivores (e.g. sea urchins, blue rayed limpets), but also indirectly for several levels within the marine food web.

The salinity model indicates that these near shore habitats will generally be unaffected by elevated salinities or only marginally affected by salinities of about 0.5-1psu above ambient. Most of the key seaweed species present in these habitats are cold temperate North Atlantic species, mainly with latitudinal distributions from mid Norway in the north to western France in the south. Some will have either northern or southern extensions of this range while others extend father at both ends of this range i.e. to sub-arctic and to north Africa (mainly the latter). Over that range all species will experience ambient average salinity of at least 1-2psu higher than at Islandmagee and therefore unlikely to have difficulty in coping with similar increases to ambient salinity over the lifetime of the project (4 years). Furthermore, recent studies into the affect of fluctuating salinity in Arctic-occurring kelp species (including Laminaria digitata, Saccharina latissima - formerly Laminaria saccharina - and Alaria esculenta) (Karsten, 2007) showed very little difference in photosynthetic activity over 2 and 5 days at salinities between 34psu and 55psu i.e. usually between 80-95% of activity of controls tested at normal salinity (34psu). These experiments suggest that for short periods at least, some kelp species can tolerate hypersaline conditions with little reduction in their photosynthetic activity and thence growth potential. Indeed, temperature and light intensity are the main factors controlling photosynthesis and the closer these are to optimal the broader is the salinity range tolerated by a species (Kirst, 1989 - [Salinity tolerance of eukaryotic algae]. None of the dominant algae present seems to be either at the northern or southern edge of their distribution range such that temperature is unlikely to be a significant factor controlling its distribution (Lüning, 1990). Ondenthalia dentata, which was observed commonly in the shallow sublittoral at Islandmagee, is the only prominent species at Islandmagee which is known to be close to the edge of its distribution at the site, in this case the southern end of its recorded range. It may therefore be at the edge of its thermal tolerance range also. However, the waters in which it was recorded by video survey will only be subject to a very small increase in salinity, (~0.5 psu) so that it is unlikely to be adversely impacted. Many of the sub-littoral red algal species may be at the edge of there light tolerance range at and close to the discharge point, which is at 27m, and therefore be subject to greater sensitivity to salinity stress. However, at these sites, the representation of red algae, indeed any algae, appears to be extremely low, based on video footage taken at these sites.

Osmotic control in plants is designed to maintain cell turgor pressure, i.e. the pressure caused by water within the cell pressing against the cell wall. This is what allows the plant to

maintain its structure shape and stability and prevent it from 'wilting'. Turgor pressure is maintained as with osmotic pressure by the gradient between the concentration of inorganic ions and small organic molecules within the cell compared to the concentration of ions in the external medium. Thus to maintain turgor (i.e. higher osmotic pressure), the total osmotic concentration inside must be higher than outside so that water will tend to flow into the cell. Exposed to a sudden increase in external salinity, seaweeds respond in the short-term (minutes to hours) by increasing the inorganic ion content within the cell, in particular within the vacuole, whereas in the long-term (over a few days), organic molecules increase in concentration within the cytoplasm through a wide range of metabolic reactions. The latter vary significantly between species and the detailed mechanisms are often not well understood. In both cases (ions and organic osmolytes), the increase in concentration is designed to maintain inward flow of water, thereby maintaining turgor pressure.

The osmotic pressure of seawater of 30psu is 92Mpa (20bar) whereas typical osmotic pressure in the cells of marine algae is in the range 2.6-3Mpa (Lunning, 1990), thus for the external salinity to become hyperosmotic to the cells contents, the salinity would have to rise considerably. This partly explains why even stenohaline marine algae can tolerate salinities fluctuations over 24hrs of between 0.5 and 1.5 times normal seawater i.e. 16-50psu. The corresponding range for inter-tidal (euryhaline) algae is 0.1-3.5 times normal oceanic salinity (see Biel 1537, 1938, 1938 and 1958 quoted in Lüning (1990). Clearly, in the Islandmagee situation, the very minor increases in salinity, which will affect the vast majority of seaweed, which are situated in shallower water close to the shore (i.e. 0-1psu), is unlikely to have an adverse impact either in the short or long-term. In deeper water, closer to the outfall, where algae will be nearer to their lower light limit for growth, the higher salinities expected (i.e. >40psu) may prove stressful (Lehnberg, 1978 quoted in Lobban and Harrison, 1994) and result in sub-optimal growth or complete elimination. However, in this area (around Site 19 in particular), the video survey showed that only red algae were present, both foliose and encrusting species, but that these were very sparse, especially, the foliose species. In view of this, such an impact, were it to be fully realised could be considered minor.

6.6.5 Summary of Impacts Based on A review of Physiology of Representative Invertebrate Groups

6.6.5.1 Inner Zone of Greatest Impact – PSU Greater than 40

In this area, confined entirely to the area of Circalittoral Sediments and associated infaunal and epibenthic communities, it expected that there will be a reduction in the diversity and biomass of infaunal and epifaunal species in general. In particular, mobile crustaceans, especially crabs and lobster will either is absent or reduced in density, due mainly to avoidance rather than mortality, which is expected to be very low among mobile epibenthic crustaceans (shrimp, lobster and crab), while small interstitial species (amphipods, isopods etc.) are likely to be more at risk. Among bivalve molluscs, king and queen scallop (*Pecten* and *Aequipecten*), will also be reduced for the same reasons and starfish, and urchins of all

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⁹ Mpa = Mega Pascal

species are likely to be present in reduced densities, while smaller specimens, and species such as Echinocyamus that live within the sediment, may be entirely absent. Polychaetes would also be expected to reduce drastically in both diversity and biomass, within this zone, with species such as Sabellaria being particularly sensitive. Along with the reductions predicted above, certain polychaete species within perhaps several groups may be more tolerant and become more abundant due to reduced competition and predation. majority of bivalve molluscs are also expected to be adversely impacted within this zone, with a significant reduction in biomass among certain species and perhaps among the smaller individuals of these in particular. Within this area also, the fertilization success of surviving adult echinoderms and perhaps all groups to a lesser extent, will be reduced as will the survival of some larval stages, especially those which settle within this higher salinity zone. The density of attached epibenthic communities, i.e. small ascidians, bryozoa and hydroids, that featured fairly prominently in video footage of the Circalittoral Mixed Sediment sites and in dredge samples from the same biotope complex, are expected to become more stunted or be eliminated within this high-salinity zone also. This is because these species have no means of extracellular osmoregulation and are non-mobile.

6.6.5.2 Intermediate Zone - PSU between 38 and 40.

This zone is also fully within the area of Circalittoral Mixed Sediments at Islandmagee and is expected to experience all the same trends as the inner zone, however to a far lower degree. Mobile crustaceans (crabs, shrimps etc.) will probably be present at pre-impact levels, especially toward the outer regions of the zone, echinoderms will remain reduced and several polychaete and bivalve families will both be reduced although, these affects will be less pronounced and less easily detectable. The impacts on attached epibenthos including, sponges, bryozoa, ascidians, cnidaria (including anemones and hydroids) may still be detectable although some encrusting species e.g. *Balanus crenatus* and *Pomatoceros triqueter*, should be largely unaffected here. Most groups spawning within this zone will likely experience reduced fertilization success and reduced survival of early larval stages, compared to unaffected sites.

6.6.5.3 Low Impact Zone - PSU between 36 and 38

In this zone it is expected that the adults of all species will be present at pre-impact levels, although interstitial polychaetes, and echinoderms may still be marginally less abundant than prior to discharge. Fertilization success and survival of early larval stages of some echinoderms, polychaetes and bivalves may be still sub-optimal, while attached epiphytic species (including sponges, bryozoa and cnidaria) may be present at reduced density or be stunted.

6.6.5.4 Non-impacted Zone - PSU between 34 and 36

It is not expected that there will be any detectable adverse impact within this zone.

6.6.6 Timeline of the Impacts

These trends will probably take at least 2 years to become fully apparent, given that year one will only see a gradual, linear, ramp up in the level of discharge, with the full discharge rates only occurring from the beginning of year 2.

6.6.7 Significance of the Impacts

The significance of the impact will depend on (i) its severity, (ii) its spatial scale, (iii) its duration, (iv) the rarity and sensitivity of the species being impacted, (v) the conservation status of the areas affected and the occurrence of similar habitats outside the impact area and (vi) any cumulative and in-combination impacts.

6.6.7.1 Severity of the Impact

The predicted reduction in both diversity and biomass of a wide range of marine invertebrates within the brine discharge mixing zone, where maximum salinity is predicted by the dispersion model to exceed 40psu, is considered severe and therefore significant. While the same trends will be evident in the mixing zone where predicted maximum salinity will range from 38-40psu, because the severity of the impact will be much lower, the significant will be minor to moderate. In the modelled maximum salinity zone of 36-38, these same trends will barely be discernible and so the significance of the impact here is considered minor to negligible. In the near background zone, i.e. 34.5-36psu, the impact is expected not to be detectable and therefore of negligible significance.

6.6.7.2 The Scale of the Impact

The spatial scale of the potentially severe impact is that the area contained within the >40psu maximum salinity contour i.e. less than 10metres from the outfall diffuser. The areas of minor to moderate impact i.e. the zone covered by the 38-40psu contour is between 2.5 and 5.5m from the outfall diffuser. Beyond this, at lower salinity levels, the significance of the impact is low enough that, arguably, this area need not be considered in terms of the spatial scale of the impact.

Scale of the Impact in the Context of the Occurrence of Similar Habitat in the Wider Area.

The area of the seabed where the model predicts significantly elevated salinities to occur comprises biotopes which broadly fit into the JNCC classifications of Circalittoral Coarse Sediment SS.SCS. CCS and Circalittoral Mixed Sediment: SS.SMx. with similarities to the sub-classifications of SS.SCS.CCS.PomB (*Pomatoceros triqueter* with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles) and SS.SMx.CMx.FluHyd (*Flustra foliacea* and *Hydrallmania falcata* on tide-swept circalittoral mixed sediment), based principally on the visible epifauna and the nature of the sediment as revealed by drop-down video, as well as diver observations. The aerial extent of these sediment biotopes along the east coast is not known. However, there are many records, especially of SS.SMx.CMx.FluHyd, noted from the Antrim and Down coasts (see JNCC web-site) and so it is likely that these biotopes or mosaics of very similar biotopes with significant overlaps in

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terms of species and substrate mix, occur widely in the region at similar depths. These biotopes are not listed in Annex I of the Habitats Directive, nor do they form part of any marine SAC within or adjacent to the study area. Accordingly, the potential impacts as outlined can be considered locally significant rather than regionally or internationally significant.

6.6.7.3 Duration of the Impact

The proposed brine discharge would proceed for 4 years with the first year taken to ramp-up to the full discharge volume, during which time (year one) the impacts would only gradually become apparent. After cessation, recolonisation and immigration would begin immediately from unimpacted or mildly impacted adjacent areas because the brine should not result in the build up of any residual contamination that would retard this. While substantial increases in both diversity and biomass should occur within the first 3 or 4 years, some slower growing and longer-lived species, e.g. bivalves such as Glycymeris may take up to ten years or more to substantially regain their original biomass. However, significant loss of community biomass would only be expected to have occurred in the central high salinity zone, i.e. greater than 40psu and therefore only in this area would full recovery appear longest.

6.6.7.4 Rarity of the Species Impacted

Many of the species recorded in those sites closest to the proposed outfall, are known to be widespread in the same and similar habitats both within this area and all along the Antrim and Down coast and the likelihood is that the vast majority of those recorded are similarly distributed. In this respect, therefore, the impact of the proposal is considered of minor significance.

6.6.7.5 Cumulative & In-combination Impacts

There are no currently existing or proposed marine discharges to the area of the proposed brine outfall, which in combination would increase the predicted impact of the proposed project. Additionally there are no other activities which would increase the impact of the proposal. Islandmagee Storage are aware of two other proposed schemes within the vicinity of Larne, one for gas storage (The North East Storage Project) and one for compressed air storage (Gaelectric Compressed Air Energy Storage) both of which would require to leach caverns within underground salt strata. It is understood that the North East Storage Project shares a mineral exploration licence with Gaelectric. It is also understood that the North Eastern Storage Project recently completed a 2D seismic survey at the end of January 2010 and are currently processing that data whilst that Gaelectric are at the feasibility study stage. Neither company has yet confirmed whether salt has been found within their licence areas and whether they are therefore able to progress with their projects. The impact of these projects can therefore not be considered within this EIS.

6.6.8 Overall Significance of the Impact

Taking account of each significance criterion addressed above, the proposed brine discharge can be considered as having a locally severe impact of limited duration on the marine invertebrate marine fauna of Islandmagee. However, the most significant impacts will be spatially confined and will not extend, for example, to structurally more complex biotopes

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closer to the shoreline and nearer to Skernaghan Point, including kelp communities, and high concentrations of brittle stars and associated diverse encrusting / attached epibenthic communities respectively.

The precise chemical composition of the brine will not be known until a sample of the salt beneath Larne Lough is recovered from the initial test well and is subjected to detailed physical and chemical testing. It is important to note however, that if the composition of the brine is found on more detailed chemical analysis to be significantly different in ionic composition relative to seawater, the impact would almost certainly be more severe although still unlikely to significantly alter the overall conclusion drawn above. In the unlikely event that the brine is shown to have elevated levels of certain heavy metals, then a more detailed appraisal will require to be undertaken as to the overall impact. Full results of the chemical testing of the salt cores recovered from the site upon drilling of the initial well will be made available to the NIEA for review prior to FEPA (or the future equivalent) consent and the discharge of any brine.

6.6.9 MITIGATION

Two main mitigation measures are recommended for the proposal, (i) a diffuser outlet designed to maximise mixing and dilution of the effluent within the shortest distance from the outfall and (ii) a gradual ramp-up in the discharge. Optimal mixing reduces the chances of organisms being exposed to excessively high salinity levels, even for a short period, thus minimising the near-field impacts. A gradual increase in ambient salinity will allow time for organisms that might otherwise succumb to osmotic shock, to acclimate to increased salinity. Ideally also, the discharge should begin in late autumn / early winter if feasible, i.e. still be quite low for the first spring / early summer invertebrate spawning and then take a further 9 months before full discharge concentrations would have been achieved.

6.7 FISHERIES

6.7.1 Introduction

This section considers the impact of the proposed development on fisheries interests in the area including:

- Crustacean fishery
- · Bivalve fishery
- Shellfish aquaculture
- Recreational sea angling
- · Salmonid migrations

6.7.2 Methodology

Information for this assessment has been compiled from the following sources:

Information on local commercial fishing and aquaculture were obtained through consultation with:

• Department of Agriculture & Rural Development (DARD), Sea Fisheries Division

Industry contacts were established with:

- · North Coast Lobster Fishermen's Association
- Northern Ireland Scallop Fishermen's Association
- Larne Lough Shellfish Association
- Information on recreational sea angling was obtained through:
- Larne Boat Club

Information on salmonid stocks and freshwater angling was obtained through consultation with:

- Department of Culture, Arts & Leisure (DCAL), Inland Fisheries Group
- Larne & District Game Angling Association

Information on monitoring of brine discharge from leaching of gas caverns at Aldbrough, East Yorkshire was obtained from:

- David McCandless (Chief Fishery Officer), UK North Eastern Sea Fisheries Committee
- Institute of Estuarine and Coastal Studies (IECS), University of Hull

6.7.3 Existing baseline

The coastline surrounding the proposed development supports an important year-round crustacean fishery for lobster and crab along with a seasonal bivalve fishery for scallop, but there is no commercial fishing activity for fin-fish. In addition, Larne Lough is a designated shellfish water with licensed areas for production of different species. Recreational sea angling also takes place in the general area and salmonids pass through the area during migrations to and from local rivers which support freshwater angling.

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6.7.3.1 Crustacean fishery

Potting for lobster and crab is a major feature of the inshore fishery along all parts of the NI coast, and the Co. Antrim coast from Rathlin to Islandmagee is the principal lobster fishing area in NI waters. Lobster (*Homarus gammarus*) is the main focus of this fishery although Brown crab (*Cancer pagurus*) and Velvet crab (*Liocarcinus puber*) are also key species, and recently the Common prawn (*Palaemon serratus*) has also become a target species.

Lobster fishermen in this area are represented by the North Coast Lobster Fishermen's Association, which covers the coastline from Carrickfergus northwards. The range of the pot fishery is restricted somewhat by the size of boats involved (<10m), as they tend to operate on day trips and therefore cannot venture far from their harbour base. There are currently 5 boats operating out of Larne and Islandmagee, fishing a wide area of the coastline which includes the area around the proposed brine outfall. Landings of lobster, brown crab and velvet crab into local ports for 2003-08 are presented in Table 6.9.

Table 6.9 Landings of lobster, brown crab and velvet crab into local ports, 2003-08

	2006			2007			2008		
Port	Lobster (kg)	Brown crab (kg)	Velvet crab (kg)	Lobster (kg)	Brown crab (kg)	Velvet crab (kg)	Lobster (kg)	Brown crab (kg)	Velvet crab (kg)
Islandmagee	1,882	5,897	1,096	2,075	5,172	1,018	374	772	223
Larne	81	1,260	114	1,449	1,593	498	883	345	92
Ballylumford	1	1	1	1	1	1	219	525	317
Glenarm	678	421	1	1,027	833	1	782	233	1
Combined	2,640	7,578	1,210	4,551	7,598	1,516	2,258	1,875	632

(Source: DARD)

The North Coast Lobster Fishermen's Association has received funding for stock enhancement through a "V"- notching programme which has been in operation since 1996. "V"- notching is a method of preserving lobster stocks which originated in the US and involves the return of egg-bearing female lobsters to the water after cutting a "V"- notch in the tail flap. If subsequently recaptured, a "V"- notched lobster must be returned to the water live. Fishermen are compensated by receiving 80% of the market value of each lobster returned to the water. The scheme is now protected by legislation so that it is illegal to land a "V"-notched lobster, which can lead to a maximum fine of £5,000. In terms of stock enhancement, the initiative is viewed as having been very successful.

In addition to the "V"- notching scheme, lobster and the crab species are each protected by minimum size limits for retention. Additional legislation to address the issue of unlicensed fishing for lobster and crab was introduced by DARD in 2008 in order to improve the management and conservation of these species in NI waters.

A lobster monitoring programme has been established in association with the Islandmagee Storage Project. Initiated in winter 2008/09 and supervised by AFBI, this study involves local fishermen deploying strings of pots in 3 defined areas – one to the north of Larne Lough, one to the south, and one in a control area around the Maidens (Figure 6.10). Details on the sex of lobster are noted along with the numbers of undersized individuals, berried females and previously notched females. Numbers of other species including brown crab and velvet crab are also recorded. This study has yielded valuable baseline data on stocks of lobster and crab species in the area of the proposed outfall and a wider expanse of the coastline. Catches of under-sized individuals along the coast are significant and highlight the importance of the near-shore habitat to the sub-adult component of the stock.

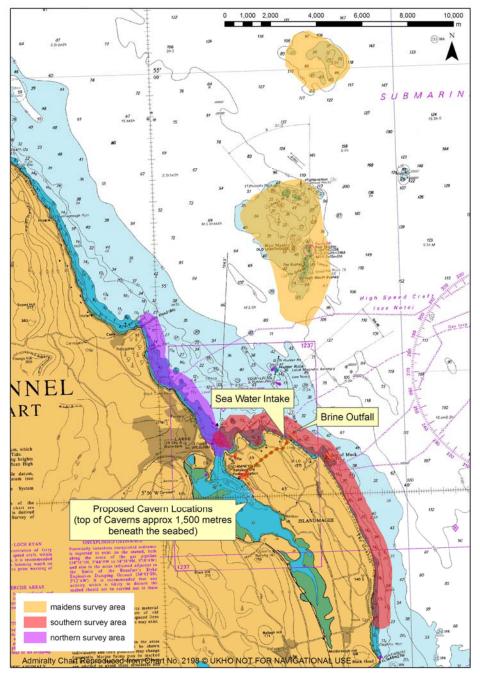


Figure 6.10Survey areas, lobster monitoring programme.

6.7.3.2 Bivalve fishery

The NE coast of N Ireland is an important area for scallop fishing. King scallop (*Pecten maximus*) are taken by small vessels towing a group of spring-loaded dredges attached to a beam and fished close in to the shore. Up to 30 Co. Down-based vessels, represented by the Northern Ireland Scallop Fishermen's Association, operate off the east coast and further afield. Most vessels are based in Kilkeel and Portavogie, with 3 operating out of Bangor. A small number of Scottish and Isle of Man boats also participate in this fishery, dredging the east Antrim coast during November/December. Landings of scallop into NI ports over recent years are shown in Table 6.10.

Since 1986 scallop fishing has been prohibited from 1 June to 31 October in ICES fishery area VIIa of the Irish Sea, to facilitate scallop spawning which takes place in 2 spawning periods during spring and autumn. This prohibition covers NI waters south of 55°N and includes the Islandmagee area surrounding the proposed brine outfall. During this period of closure some local vessels move north to fish scallop grounds off Lough Foyle and the Co Donegal coast.

Table 6.10 Landings of King scallop to NI ports, 2003-08

Vacu	Scallop landings					
Year	Weight (t)	Value (£)				
2003	479.92	655,639				
2004	580.56	750,938				
2005	453.35	615,797				
2006	346.52	495,479				
2007	442.73	623,424				
2008	601.94	1,708,771				

(Source: DARD)

Scallops must have a minimum shell length of 110mm to be legally landed for commercial use. This minimum legal landing size within ICES rectangle VIIa ensures that scallops spawn at least twice before becoming vulnerable to direct fishing mortality. Further conservation regulations were introduced in 2008 reducing the permitted daily fishing time, limiting the number of dredges fishable by each boat and extending regulation to "fishing by any means" including divers.

Scallop surveys are carried out annually by AFBI in 5 defined areas extending from the southern end of the Ards peninsula to Islandmagee. A considerable body of data has been accumulated since 1985 on relative abundance and age structure of the population.

6.7.3.3 Shellfish Aquaculture

Larne Lough has been designated under the Shellfish Waters Directive (79/923/EC), subsequently repealed by the codified Shellfish Waters Directive (2006/113/EC). The Directive aims to:

"protect and where necessary improve the quality of coastal and brackish water bodies in which shellfish live and grow, in order to contribute to the quality of edible shellfish products."

There are 5 areas licensed for shellfish aquaculture in Larne Lough extending over 70ha, with specific sites licensed for production of one or more species (Figure 6.11). Cultivation has focussed on Blue mussel (*Mytilis edulis*) and Pacific oyster (*Crassostrea gigas*), while native oyster (*Ostrea edulis*), Manila clam (*Tapes semidecussata*) and native clam are also produced.

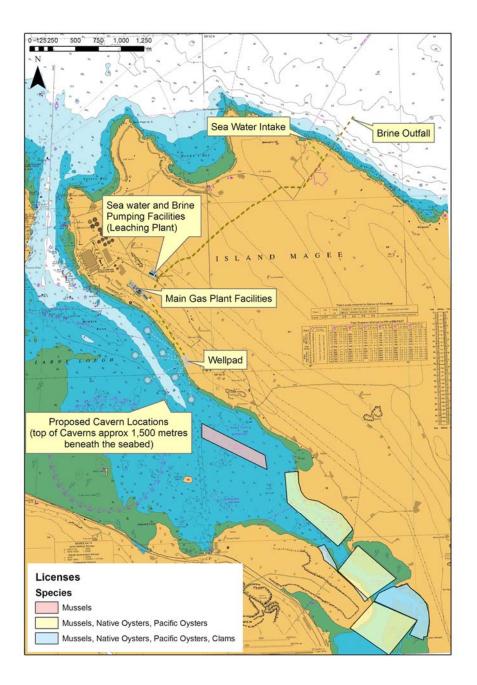


Figure 6.11 Areas licensed for shellfish production in Larne Lough

(Source: DARD)

Mussels are produced by bottom culture based on re-laid seed (or spat) for growing on to harvest size. The spat is dredged from known areas around the Irish coast where it has settled in abundance - this takes place between July and November, and the seed is re-laid at lower density to promote improved growth and meat content. Harvesting of mussels is

generally between November and March but can occur throughout the year. Native oyster are also bottom grown, as are clams which are placed in the inter-tidal area.

Pacific oyster are grown in bags on trestles placed on the inter-tidal area and reach market size in 2-3 years. The produce is harvested during the winter months for sale to specialist outlets in Europe.

Due to its limited area, the Lough will never be a major producer of shellfish in comparison to other sea loughs in Northern Ireland. In 2004 DARD initiated the SMILE project, a two-year study with the aim of "developing dynamic ecosystem level carrying capacity models for the five sea lough systems in Northern Ireland" (SMILE Report, 2007). This exercise estimated a sustainable rate of production for the lough at 300 tonnes of mussel and 9 tonnes of Pacific oyster.

Recent production figures for the lough are summarised in Table 6.11; since 1998 there have been continuing problems with water quality which have impacted on production. Initial difficulties were encountered through sewage pollution due to lack of treatment, while recent problems may be linked to an industrial discharge. Mussel production peaked at 200 tonnes 2003 and 04 but has since declined to a negligible level, while production of Pacific oyster has declined from 30 tonnes 1998 to a very low level in recent years.

Table 6.11 Shellfish production in Larne Lough, 2003-07

	2003		200)4	2005		
Species	(tonnes)	(value £)	(tonnes)	(value £)	(tonnes)	(value £)	
Blue mussel	200	80,000	200	55,000	163	81,500	
Pacific oyster	10.4	15,380	14.6	20,000	7.2	9,300	
	2006		2007				
Blue mussel	nil	n/a	nil	n/a			
Pacific oyster	0.6	1,245	1.05	1,450			

(Source: DARD)

Producers are represented by the Larne Lough Shellfish Association and have embarked on a significant development programme for the Lough, through the re-introduction of native oyster with 3 million juveniles re-seeded between 1997 and 2008. In the 1920s the Lough contained 300 acres (>120ha) of native oyster beds which were lost in subsequent years through dumping of spoil from Magheramorne quarry (W. Johnston, *pers comm.*).

Native oyster can be infected by the blood parasite *Bonamia ostreae* which is now widespread in oysters through continental Europe and also occurs in some oyster growing areas in the UK and Ireland. Similarly the Pacific oyster industry in Ireland and Europe has recently been affected by widespread outbreaks of Oyster Herpes Virus leading to serious

mortalities. Both of these conditions have led to movement controls and zoning of areas to prevent further infections. However, Larne Lough remains a disease-free area and local producers have developed a new hatchery technology with a view to establishing microhatcheries in each shellfish bay in Ireland. This system should also have considerable potential for export on an international basis.

6.7.3.4 Recreational sea angling

The Larne & District Sea Angling Club consists of a small group of 20-30 individuals who fish in the local area and also travel widely to competitive events throughout Ireland. The club is mostly involved with beach fishing and does not appear to have any established facilities for the mooring or launching of boats.

The main boat fishing activity in the area is through Larne Boat Club which operates out of a small premises adjacent to Larne Harbour with slipway access to the Lough. The club has a membership of 74 and members fish in all shore areas within reach of the harbour including the Islandmagee shore in the area of the proposed brine outfall.

The main fish species encountered are:

Gurnard Trigla lucerna
Cod Gadus morhua

Pollack Pollachius pollachius
Dogfish Scyliorhynus canicula

Ling Molva molva
Ballan wrasse Labrus bergylta
Mackerel Scomber scombrus
Pouting Trisopterus luscus
Spurdog Squalus acanthias
Greater Spotted Dogfish (Bull Huss) Scyliorhinus stellaris

6.7.3.5 Migratory Salmonids

Atlantic salmon and sea trout migrate to and from the Larne (Inver) and Glynn rivers, both of which discharge into Larne Lough (Figure 6.12). Both rivers were designated as "salmonid" in 2003 under an extension of the Surface Waters (Fish Life Classification) Regulations (Northern Ireland) 1997, which implements the EC Freshwater Fish Directive (78/659/EEC). In addition the Atlantic salmon is listed under Annexe II of the EU Habitats Directive and is therefore afforded special protection measures within designated Special Areas of Conservation (SACs).

Salmon and sea trout spawn in these local rivers and develop as juveniles before migrating to sea as smolts, usually in their second or third year; the adult fish then return to their natal rivers in the following year. Both species are also the focus of a sport fishery in the Inver River which is controlled by the Larne & District Game Angling Association with 70-80 members. The Association received funding for development under the EU Special Support Programme for Peace and Reconciliation, and has carried out extensive river restoration works and the development of a hatchery.

Sea trout appear to be reasonably abundant in both rivers but salmon numbers are reported to be very low in spite of a 5-year restocking programme completed in 2005 (V Lilley, pers comm.).

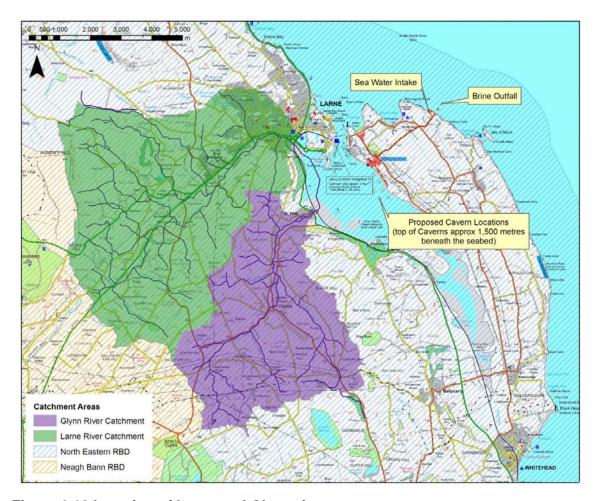


Figure 6.12 Location of Larne and Glynn rivers

6.7.4 Potential impacts

6.7.4.1 Disposal of Brine to Sea

The principal concern with regard to fisheries interests relates to the impact the brine discharge may have on the behaviour and survival of key local species during the leaching process.

The main difficulty in assessing the potential impacts is that the phenomenon of hypersalinity in this type of location with its associated biology, is most unusual and few studies have been carried out to assist with prediction of these impacts. Clearly salinity is a key environmental variable which affects the performance and distribution of marine organisms; abrupt changes in salinity or prolonged exposure to unfavourable salinity can lead to sub-lethal or lethal effects. Various studies on altered salinity have been carried out but most involve investigations on reduced salinity, usually with estuarine species, rather than increased salinity.

However the brine dispersion modelling carried out in relation to this proposal would suggest that brine dispersal will be very effective and therefore impacts on the biota should be highly localised. In addition, a similar gas storage project by Scottish and Southern Energy (SSE) at Aldbrough, East Yorkshire has been closely monitored since 2005 and has demonstrated adequate plume dispersion with no detrimental impacts observed (Jacobs Engineering UK Ltd, 2008). Brine disposal at Aldbrough also coincided with one of the most productive lobster and crab fisheries in the UK which appears to have been unaffected by the development (D McCandless *pers comm.*).

Brine dispersion modelling

The results of brine dispersion modelling at the Islandmagee discharge have predicted that:

- the brine will tend to sink to the seabed due to its high concentration and density
- a dilution of >200:1 producing a salinity of 36.6psu is predicted to be achieved at 5-10m from the discharge
- a maximum increase of less than 4psu (outside of the immediate vicinity of the diffuser) was recorded during simulations
- any salinity increase in excess of normal seasonal variation is anticipated to be restricted to the initial mixing zone <100m from the outfall
- there will be a significant decrease in salinity up through the water column with no significant impact in the surface layer

On the basis of these projections, the most extreme result is that the bottom layers will experience salinities in excess of 36.6psu up to a maximum distance of 10m from the outfall (i.e. within a diameter of 20m) for two short periods during the tidal cycle, at slack water. This is equivalent to an area of $314m^2$ although, in practice, the precise position of this footprint is likely to alter due to minor variations in water movement and brine dispersion at slack water. The benthic flora and fauna impact assessment in Section 6.2 of this Chapter anticipates that there will be no detectable adverse impact outside of this zone i.e. at salinities in the 34-36psu range. Within this zone, although modelling predicts effective dilution and dispersion through most of the tidal cycle, salinities in excess of 36.6psu will occur regularly and will have implications for benthic species within this area.

Impacts on epibenthic communities within this zone have been predicted to vary according to distance from the outfall and resultant variations in peak salinity experienced. Closest to the outfall at salinities in excess of 40psu, it is anticipated that mobile crustaceans, including lobster and crab, will either be absent or at reduced density due mainly to avoidance rather than mortality. Scallops are also expected to be at reduced density due to avoidance as they are capable of significant movements by rapid closing of the valves and the ejection of jets of water adjacent to the hinge line. Spawning of these species is likely to be impaired with reduced fertilisation success and reduced survival of larval stages. At lower salinities (36-40psu) according to distance from the outfall, these impacts are expected to be reduced as the influence of the brine discharge diminishes. However in effect, the zone of elevated salinity in excess of 36.6psu in which any detectable impacts are likely to be observed will be highly localised.

Impacts on commercial fishing for shellfish through damage to stocks either by mortality or evacuation of the area are likely to be confined to the immediate locality; probably no more than 100m form the outfall. Impacts on migratory salmonids are unlikely as these species are known to migrate in the surface layers which will not be subject to any significant increases in salinity. Fin-fish species in general, due to their mobility, will be able to avoid the zone of raised salinity around the outfall.

Aldbrough Gas Storage Project

This project consists of 5 gas caverns with leaching commenced in 2005 and now complete. An application for a second phase of construction including a further 9 caverns received planning permission in 2007. During the first 3 years of the project, for which monitoring results have been obtained by RPS, a peak discharge rate during year 1 of the leaching process was recorded at 1,942m³/hr with 235g/l total dissolved solids (~235psu) at an average of 721m³/hr and 171g/l total dissolved solids. In subsequent years the flow rate was lower but the concentration was higher (Table 6.12). In comparison the Islandmagee project is based on a maximum projected flow of 1,000m³/hr with a maximum salinity of 260psu. The consent limits at Aldbrough had been set at a flow rate of 2,052m³/hr with 284g/l total dissolved solids and none of the data recorded during the leaching period exceeded or approached this limit.

Table 6.12 Summary of discharge flow rates and total dissolved solids at Aldbrough

	Flow rate (m³/hr)						
Consent limit	2,052						
	Year 1	Year 1 Year 2 Year 3					
Maximum	1,942	1,719	1,508				
Average	721	745	576				
	Total	dissolved solids	s (g/l)				
Consent limit		284					
	Year 1	Year 2	Year 3				
Maximum	225	240	262				
Average	171	201	110				

(Reproduced from Jacobs Engineering UK Ltd, 2008)

In addition to direct monitoring of the discharge at Aldbrough, continuous monitoring of ambient salinity was undertaken through the deployment of sonde devices on the seabed at distances of approximately 50m and 250m from the outfall diffuser. The data obtained indicated effective dispersion of the brine discharge within the consent limit of 40g/kg (~40psu) at 250m (Table 6.13).

These results would suggest that the brine discharge at Aldbrough may have had a wider zone of influence than is projected for Islandmagee. However it should be noted that the outfall at Aldbrough is situated in only 10 metres water depth thus reducing the potential for dispersion and the maximum flow rates recorded at Aldbrough were 50-90% greater than proposed for Islandmagee.

Table 6.13 Summary of salinity monitoring using sondes at Aldbrough

Distance from	Maximum ambient salinity (psu)					
diffuser (m)	Year 1	Year 2	Year 3			
50	41.0	46.0	44.7			
250	37.0	37.1	36.9			

(Compiled from Jacobs Engineering UK Ltd, 2008)

Epifaunal and fish communities have also been monitored at Aldbrough through beam trawl and video surveys while crustacean stock assessment has been undertaken using strings of pots deployed close to the diffuser and extending through the 250m mixing zone. Full results of these investigations throughout the leaching period are not yet available but we understand that epifaunal and fish communities appear to be within the normal range of variation for a highly dynamic coast with no clear indication of significant impacts immediately adjacent to the discharge (D McCandless, *pers comm.*).

A means of illustrating minimum potential impacts was devised using sentinel animals held in pots within the dispersion plume at various distances from the discharge point (Procter, 2005). Again, full results are not yet available but it is reported that no differences were observed between control and "treatment" strings of pots with mortalities not exceeding an agreed 35% trigger level (D McCandless, *pers comm.*).

6.7.4.2 Suspended Solids

Elevations in the concentration of suspended solids can be a potential problem during the construction phase of any marine engineering project, with the potential to impact on both finfish and shellfish populations. Initially an elevation of suspended solids concentrations in the water column can interfere with the gas exchange capabilities in fish, while subsequent settlement of sediments on the seabed can result in the burial and smothering of epifaunal species including lobster and crab.

The level of suspended solids in the brine discharge at Islandmagee is predicted to be low. At Aldbrough measurements of suspended solids in the abstracted sea water actually exceeded that within the brine discharge in almost all samples, with the caverns effectively operating as settlement tanks during the leaching process.

Construction of the offshore section of the outfall pipe at Islandmagee could be a potential cause of raised suspended solids but it is proposed that this section be constructed by Horizontal Directional Drilling (HDD) as opposed to open trenching. As such, the only source of suspended solids will be at the point where the drilling equipment breaks through the seabed. This will result in a temporary localised suspension of drilling mud and cuttings into the water column. The cuttings will settle out within a few metres of the breakout while the finer particles in the lubricant drilling mud (bentonite) will be dispersed rapidly and widely by the tidal currents eventually settling out. It is not anticipated that this discharge will present

any perceptible increase in turbidity beyond the discharge period of 3 hours and confined to the immediate area around the break out point. There will therefore be no resultant impact on fisheries interests in the area due to the release of suspended solids.

6.7.4.3 Impingement at sea water intake

The sea water which will dissolve the salt to form the gas caverns will be drawn from an intake sited on eastern shore of Islandmagee. The intake structure will consist of two 450mm diameter pipes mounted in an intake structure fitted with coarse and fine screens with a large surface area relative to the combined cross-section of the pipes. It is anticipated that there will be some degree of impingement of fish and invertebrates on the screens. This is a well documented phenomenon at power station intakes for cooling water throughout the UK including the Ballylumford and Coolkeeragh plants in N Ireland, both of which are monitored through an on-going impingement survey carried out by NIEA since 1989.

Peak flow velocities at the Islandmagee intake screens are predicted to be in the order of 0.5-0.6m/s and, as this is within the burst swimming speeds of some fish species, many will be able to avoid impingement. However it is likely that some level of impingement will occur at the screens while smaller fish and invertebrates along with planktonic organisms will pass through the screens and become entrained in the abstracted water. This will not impact on commercially important species in the area.

6.7.5 Mitigation measures

A series of mitigation measures is proposed to ensure that any impacts are minimised.

6.7.5.1 Intake Design

The design of the abstraction system will be important to minimise the level of impingement by fish and invertebrate organisms. In order to facilitate fish taking avoiding action the total area of fine screens area should be many times greater than the combined cross-section area of the 2 abstraction pipes. The screens should also be placed at sufficient distance from the pipes to ensure an even flow over their complete area which will minimise flow velocity at any point.

6.7.5.2 Monitoring of Brine Dispersion

It is recommended that brine dispersion be monitored continuously through the deployment of real-time monitoring devices located on the seabed at selected positions throughout the mixing zone. In addition it is suggested that, in advance of the commencement of leaching, a trigger level be set for salinity at a pre-determined distance from the outfall. Exceedence of the trigger level would result in a temporary suspension of leaching.

6.7.5.3 Use of Sentinel Organisms in Monitoring Programme

The use of sentinel organisms within the mixing zone and at control sites may be effective in monitoring the impact of the brine discharge on commercially important species. Lobster, crab and scallop could be held in pots or alternative devices to monitor mortality rates at various distances from the outfall in comparison to control sites; trigger levels may be based on baseline mortality rates established at the control sites. These experiments may also

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facilitate a more detailed assessment of organism health in the area surrounding the discharge.

6.7.5.4 Monitoring of commercial shellfish stocks

The lobster monitoring programme initiated in 2008/09 as part of the gas storage project has yielded valuable baseline data on stocks of lobster and crab species in the area of the proposed outfall and the Co. Antrim coastline extending both north and south. It is recommended that this programme be continued through the leaching phase and beyond in order to detect any impacts in terms of reduced abundance or deterioration in condition. In addition it is suggested that the annual scallop survey carried out by AFBI could be extended to include an area in the more immediate vicinity of the proposed outfall.

6.7.5.5 Stock enhancement

The V-notching scheme administered through the North Coast Lobster Fishermen's Association appears to have been very effective in the restoration of local stocks. Additional funding of this initiative through the gas storage project would help to ensure that the programme continues for an extended period. Lobster stocks may also be enhanced through the purchase and release of mature females. Enhancement of king scallop could be considered but this would depend largely on a reliable natural source of scallop spat.

6.7.5.6 Liaison with fishing industry

Throughout the construction phase of the project and the monitoring programme it will be important to involve stakeholders, in particular participants in the local fishing industry. To this end it is suggested that a fishing industry stakeholder group be established to ensure full engagement with the industry so that fishermen are adequately informed with regard to project progress and information from the monitoring programme as it becomes available.

6.7.6 Predicted Residual impacts

6.7.6.1 Commercial fishing

Provided the dispersion of brine from the outfall diffuser approximates to the predicted levels outlined within Chapter 9.0 "Coastal Processes" there should be no significant impact on the productivity of local fishing operations for lobster, crab and scallop. Localised impacts in the immediate area of the outfall during the leaching period could be offset through stock enhancement measures. Local impacts could be more significant if the ionic composition of the salt deposits is found to be significantly different from that of normal seawater or if this material is found to be contaminated by heavy metals; this will be determined as soon as core samples are recovered from the first borehole, prior to any leaching commencement.

6.7.6.2 Shellfish aquaculture

The brine dispersion modelling indicates that there is no possibility of the dispersion plume penetrating into Larne Lough during the flood tide. Although the plume is shown to spread northwards towards the inlet of the lough, dispersion will be very effective and salinity will remain within normal levels of variation. There will therefore be no residual impacts on aquaculture operations within the Lough.

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6.7.6.3 Impingement at Sea Water Intake

Careful design of the seawater intake structure will minimise the entrapment of fish and invertebrates at the screening system but level of impingement will occur but this will not be significant in terms of local fish and shellfish stocks.

6.7.6.4 Salmonid Migrations

No residual impacts are predicted.

6.7.6.5 Sea Angling

No residual impacts are predicted.

6.8 MARINE MAMMALS

A survey of marine mammals in the Larne Lough, Islandmagee and Maidens areas has been undertaken to assess the likelihood of any potential impact of the proposed gas storage project brine outfall works on marine mammals in the area.

6.8.1 Methodology

Coastal surveys were planned, using the North Irish Diver RIB, with the principal objective of locating marine mammals, particularly small cetaceans, in the coastal waters in order to determine any coastal areas used regularly for foraging. A second objective was to assess the species, numbers and possible breeding activity of seals on the Maidens, Isle of Muck, and nearby coastal areas. Systematic line transects were not used, since the primary survey aim was not to estimate the overall porpoise population (e.g. Berrow et al., 2009), seal haulout sites were also being surveyed, and such a survey would have required much more specialist personnel, planning, boat and analytical time.

Five boat surveys were carried out when the weather was considered to be suitable for spotting porpoises, with an estimated sea state of 0–3 (Table 6.1). Harbour porpoise surveys should not be carried out in sea state >3, and ideally should be carried out in sea states 0–1 to ensure that most animals are spotted (Berrow et al., 2009). Each trip lasted 2-3 hours, and covered as much of the study as possible (Figure 6.13). The boat pilot (Peter Steele) and crew are experienced at locating porpoises in the area, and their advice was taken as the most promising route to follow. Two observers searched ahead on each side of the boat, and one person searched to the side and the stern. The GPS locations of the boat when cetaceans and seals were sighted were recorded with a hand-held GPS and later downloaded to Garmin 'Map source' and Google Earth.

Table 6.14 Seal and porpoise survey days with TSR on North Irish Diver

Date	Wind force	Equivalent sea state	Tide state	Porpoises seen
Sep 27 2008	3–4	2–3	Mid-ebb	Yes
Nov 02 2008	2	1	Mid-ebb	Yes
Dec 14 2008	2–3	1–2	Mid-ebb	No
July 12 2009	3 lessening >1	2 > 0–1	Mid-ebb	No
Sep 11 2009	1–2	0–1	Low water	Yes

Further cetacean records were obtained from the same boat and pilot on October 10 2008, July 15 2009, July 29 2009 and September 20 2009 (P. Steele, pers. comm.). Additional records of casual sightings of porpoises, dolphins and small whales in the area were

obtained from the Irish Whale and Dolphin Group (IWDG) website¹⁰ and also transferred to Google Earth.

6.8.2 Study Area

The study area was the northern area of Larne Lough, the sea area between Larne Lough, the Isle of Muck and the Maiden Rocks (Figure 6.14). The dark blue arrow shows the approximate location of the proposed brine outfall.

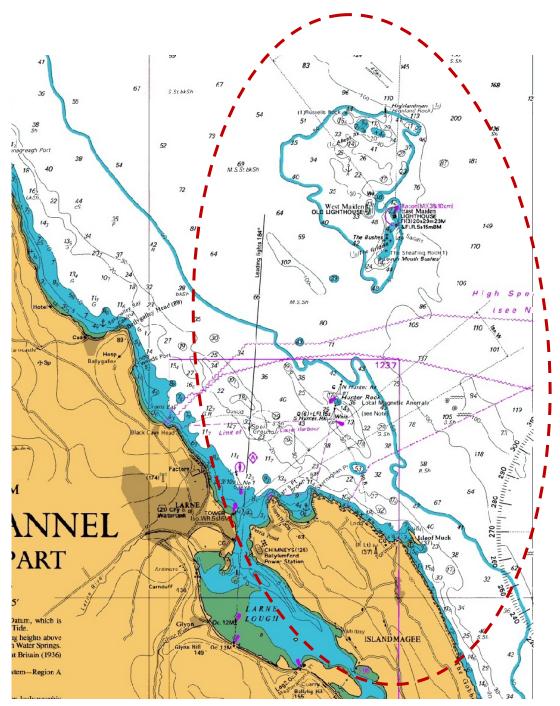


Figure 6.13 Study Area (Indicated by Broken Red Line)

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¹⁰ http://www.iwdg.ie/iscope/sightings

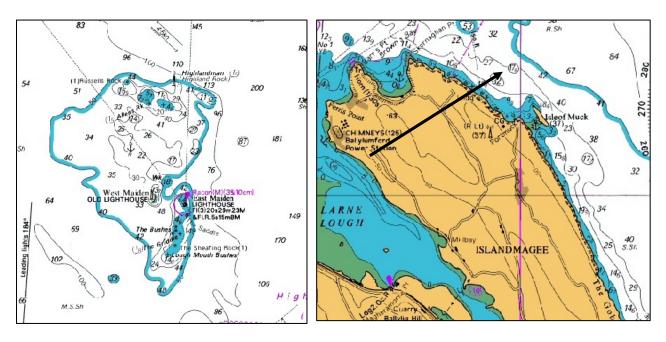


Figure 6.14 Detail of the Maiden Rocks (left) and the Isle of Muck area of Islandmagee (right). The proposed brine outfall is shown by the dark blue arrow

6.8.3 Sightings of harbour porpoises (*Phocaena phocaena*)



Plate 6.73 Harbour Porpoise

Photo: Peter Steele

The boat surveys found porpoises principally in the vicinity of the Maidens, mainly in areas of tidal turbulence (Figure 6.15). Most records appear to be within the relatively shallow shelf, up to c. 40m depth, of the Maiden rocks, rather than in the surrounding deeper water. No other cetaceans were seen during the surveys. Groups ranging from about 6 to 30 individuals appeared to be feeding, with individuals seen repeatedly diving in all directions within an area surrounding the boat. A total of about 60 porpoises were estimated to be present in the area during the 11/09/09 survey. Porpoises were also sometimes spotted in smaller groups of c. 2–3 individuals (), which often seemed to be travelling rather than feeding. Other sightings of porpoises from North Irish Diver (NID) records 2008–09 and the IWDG records (2000–09) suggest a second cluster of porpoise sighting in the area of tidal

turbulence to the seaward side of the Isle of Muck (Figure 6.15). A single observation in July 2009 of a sei or minke whale feeding for about 45 minutes lies within this same area (Plate 6.74).

The IWDG website map of porpoise, dolphin and small whale sightings in Co. Antrim 2000-09 indicates three distinct clusters of harbour porpoise sightings, one in the Whitehead area of Belfast Lough, one in the Isle of Muck area off Islandmagee, and one along the north coastline in the Portrush area^{11.} The IWDG records for the Larne, Islandmagee and Maidens area indicate that harbour porpoises are the most commonly seen cetacean, and probably the only species which may be considered resident in the local area. Common dolphins are the next most commonly seen species, and there have been occasional sightings also of bottlenose dolphins and unidentified dolphins. However, all dolphin species appear to be transients in the area.





Plate 6.74 Whale observed feeding seaward of the Isle of Muck on 15/07/09.

(Photos: Dave Allen, from North Irish Diver)

Table 6.15 Locations and no. porpoises seen from survey boat (North Irish Diver)

Date	°N	°W	No. individuals	Notes
During dedicat	ed surveys by	Tara Seal Rese	arch	
27/09/08	54 54.769	5 43.304	2	c. 250m seaward of boat, moving away
	54 57.302	5 45.058	6–8	Apparently feeding, dispersed
				individually
02/11/08	54 54.997	5 44.686	c. 20	Apparently feeding, dispersed
				individually
	54 57.458	5 43.862	1	Heading towards Highland Rock
	54 57.499	5 44.132	3	2 ahead, one behind boat
	54 57.498	5 44.317	5–6	Apparently feeding, dispersed
				individually

¹¹ It is possible that these apparent porpoise hotspots could be more a reflection of observer hotspots than porpoise distribution.

Date	°N	°W	No. individuals	Notes
11/09/09	54 54.546	5 44.763	2	Travelling SE
	54 56.898	5 43.097	c. 20–30	Apparently feeding, dispersed
				individually
	54 56.435	5 43.166	Same group	Continue to see them en route to West
				Light
	54 56.125	5 43.425	4	
	54 55.615	5 43.363	More of group	
	54 55.763	5 43.336	2 groups, c.	Different groups – one near boat, other
			30 altogether	c. 200m out to sea
	54 55.823	5 43.289	2+	
	54 55.742	5 42.962	2+	
	54 55.252	5 42.139	2	
	S	Supplementary	records from Nor	th Irish Diver
29/10/08	54 57.208	5 43.550	2	
	54 51.232	5 42.127	2	
	54 51.027	5 42.886	2	
15/07/09	54 51.055	5 42.989	1 sei/minke	Feeding, observed for c. 45 minutes in
			whale	same area
29/07/09	54 50.95	5 42.92	c.8	
20/09/09	54 51.20	5 43.10	8–10	Reported here over period of c. 1 week

Records from 2008–09 Islandmagee Storage Project dedicated surveys (diamonds); IWDG records 2000–09 and North Irish Diver records (2008–09) (circles). The pink marker W is the location where the whale (sei or minke) was observed feeding in July 2009. The Maidens rocks and rocks used by seals in Larne Lough are indicated by silver balls. The circled areas surround the areas of most frequent overall sighting of porpoises. The blue arrow represents the approximate location of the proposed brine outfall ending at the 20m contour.

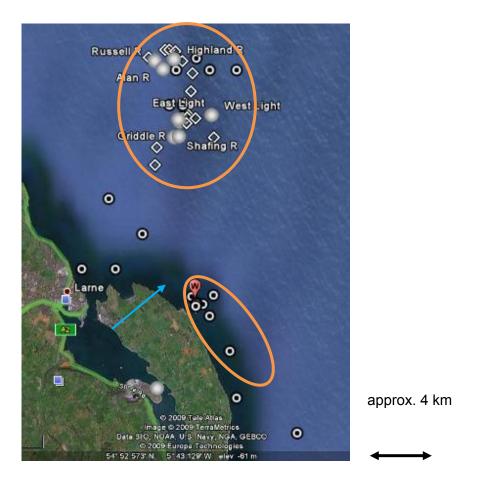


Figure 6.15 Locations of harbour porpoises in the study area

The number of porpoises seen in each group by the survey team and the North Irish Diver between September 2008 and September 2009 and the frequency of group size sightings were very similar to the IWDG records, with groups of 1–3 and 4–10 individuals being seen more often than larger groups (Table 6.16). It is probable that smaller social units coalesce into larger groups where there is good foraging opportunity. However, the group sizes recorded by Berrow et al. (2009) for the Blasket Island area, by Hastie et al. (2003) for the Moray Firth and for Teilmann (2003) in Danish waters are generally smaller than we recorded in this study (averaging only 1–3). Berrow et al. (op. Cit.) comment that areas of porpoise concentrations are probably at feeding areas, and tend to occur where currents are very strong or at reefs where fish prey items may occur at high densities. This concurs with the observations in this study.

Table 6.16 Group size of porpoise sightings

Curvey		Group size			
Survey	1–3	4–10	>10		
Islandmagee Storage Project/North Irish Diver 2008–09	10	6	4		
IWDG 2000-09	8	7	3		



Plate 6.75 Two porpoises surface, part of group of 20–30 seen to north of Maidens on 11/09/09

The IWDG casual sightings records for this area suggest that porpoises may be seen here at most times of the year, but have been most often recorded in August and next most often in January and July. However, the sightings recorded in the dedicated Islandmagee Storage Project surveys were in September (twice) and November, with none in July or December. Probably all surveys to date have been too infrequent, opportunistic and at varying states of tide and weather to be able to indicate any seasonal variation in porpoise abundance in the Maidens/Islandmagee area. Until there is more systematic data, we should assume that porpoises are resident in the area year-round, and forage particularly in the tidal race areas around the Maidens and to the seaward side of the Isle of Muck.

At present there appear to be no coastal SACs in Northern Ireland for which the harbour porpoise is an qualifying feature. Since porpoises appear to be resident in the Maidens/Islandmagee area, and this is one of only three such areas along the Antrim coast, it may be that this area should be considered for a porpoise SAC. In that case, a more systematic survey than the present one, using line transects and acoustic monitoring, should be used to assess the porpoise abundance in this area, and adjacent areas such as the mouth of Belfast Lough.

6.8.4 Sightings of seals (Halichoerus grypus and Phoca vitulina)

Photographs of seals at the Maidens and at Larne Lough are presented at the end of this section.

Grey seal (*Halichoerus grypus*). Grey seals were regularly seen on all surveys dispersed around the eight principal rocks of the Maidens group (Table 6.17). The maximum number seen was 30–40 in the July and September surveys. Mixed haul-out groups of several

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animals included all ages and sexes. However, adult male and female 'pairs' were seen hauled out or swimming together, on at least 11 occasions, on the July, September and November surveys. Juvenile and subadult grey seals were identified on at least 7 occasions in addition to being spotted within larger groups. One white-coat pup was seen at West Maiden on November 02 2008. West Maiden was considered to be the most suitable of the Maiden rocks for grey seal pupping, owing to the height out of the high tide zone of sheltered boulders suitable for pups. Only one grey seal was observed in open water, diving repeatedly in water about 90m depth (Table 6.17).

An unidentified seal, identified as neither a grey nor a common seal, was seen beside a male-female grey seal pair at West Light on 27/09/09. This seal might be a female hooded seal (*Cystophora cristata*) vagrant.

Common seals (*Phoca vitulina*). A maximum number of 7 common seals were observed at the Maidens, usually on Sheafing Rock, although one adult and one juvenile were seen at West Light on 11/9/09. Additionally, 3–4 common seals were observed at the haul-out site at Mill Bay in Larne Lough (Table 4). There was no evidence of common seal pupping in July and no evidence that the Maiden rocks are a significant moulting site for common seals12. No common seals were observed in the vicinity of the Isle of Muck. The small group of common seals at Mill Bay in Larne Lough seems to be resident (P. Steele, *pers. comm.*), but it seems likely that the few common seals at the Maidens are transient animals, possibly feeding in the area.

Table 6.17 Seal sightings at Maidens and Isle of Muck, surveys Sep-Dec 2008

Location	N	w	27/09/0	02/11/0	14/12/0	12/07/0	11/09/0
Location	N		8	8	8	9	9
					Grey Seals		
Larma Lavreh	54	E 44 66	Na		No	0	4
Larne Lough	48.85	5 44.66	Nc	nc	Nc	0	1
Doutmand Island	54	F 40 04	0	0	0	4	0
Portmuck Island	51.02	5 43.34					0
	54	5 43.70	0	1	0	2	0
East Light	55.56						0
Obseries Deels	54		4	3	0	5	3
Sheafing Rock	55.66	5 43.92					
Caddla Bask	54	F 40 70	4	0	0	0	4
Saddle Rock	55.75	5 43.70	4	2	0	2	4
	54	5 40 00	0		2	0	4
Griddle Rock	55.29	5 43.69	0	0			1

¹² The survey on September 11 2009 was a little late for a count of moulting common seals, but it would be expected that about half the moulting seals would still be visible in the first half of September.

Location	N	w	27/09/0 8	02/11/0 8	14/12/0 8	12/07/0 9	11/09/0 9
West Light	54 55.91	5 44.33	7 + 1 Unid	12+1P	c. 10	5	7
Alan Rock	54 57.01	5 44.41	8-10	0	0	15–20 (w)	6
Russell Rock	54 57.23	5 44.78	1	0	0	2	6
Highland Rock	54 57.27	5 43.92	2	0	0	0	5
Open water	54 54.82	5 43.19	0	0	0	1	0
TOTAL			28	18+1P	10	36–41	33
				Co	mmon sea	als	
Larne Lough	54 48.85	5 44.66	Nc	nc	nc	3	4
Portmuck Island	54 51.02	5 43.34	0	0	0	0	0
East Light	54 55.56	5 43.70	0	0	0	0	0
Sheafing Rock	54 55.66	5 43.92	7	1	0	1	1
Saddle Rock	54 55.75	5 43.70	0	0	0	0	0
Griddle Rock	54 55.29	5 43.69	0	0	0	0	0
West Light	54 55.91	5 44.33	0	0	0	2 (incl 1J)	0
Alan Rock	54 57.01	5 44.41	0	0	0	0	0
Russell Rock	54 57.23	5 44.78	0	0	0	0	0
Highland Rock	54 57.27	5 43.92	0	0	0	0	0
Open water			0	0	0	0	0
TOTAL			7	1	0	6	5

6.8.5 Comments on possible impact of the proposed construction and operation of the brine outfall

The predictable impacts of the proposed brine outfall works on marine mammals in the area would include possible effects of noise in the sea and vibration in the seabed during the construction phase followed by the possible adverse effects of brine emitted from the outfall during the period of operation.

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6.8.5.1 Construction Phase of Brine Outfall and Sea Water Intake

Both seals and cetaceans are known to be sensitive to underwater noise and vibrations in the seabed. Response of animals to noise includes avoidance behaviour (swimming rapidly away from the sound source), temporary hearing loss (Temporary Threshold Shift – TTS) and disorientation of cetaceans (due to interference with the animals' sonar system). Documentation of marine mammal behaviour during seismic surveys in the UK has found an increased tendency for cetaceans to breach, jump and somersault up to 4km from the source and engage in fast swimming for up to 3 km from the source (Stone, 1999). Both grey and harbour seals have been found (by telemetry studies) to respond both behaviourally and physiologically to experimental seismic surveys. 10 grey seals monitored showed an avoidance reaction, increased the swimming speed and switched from foraging to transit dives. One of two harbour seals tested showed a drop in heart rate (to 10 beats/min), which stayed low for 55 sec (Thompson et al., 1998). Fish in the vicinity of an underwater explosion may also be killed. For example, it was estimated that 5,000 fish died from a 5-pound (2kg) explosive charge in Puget Sound ('The Olympian', 2002).

At this stage of the preliminary design, it is not certain whether blasting will be required at the site of the Sea Water Intake pumping station. Upon completion of the pre-construction ground investigation studies, if it is determined that blasting is required; a detailed methodology will be prepared and submitted with the environmental management plan for approval by the NIEA.

In order to estimate a safe underwater distance from the explosion for marine mammals, the weight of the explosives, the frequency of the sound and the initial sound intensity need to be known. As an example, acoustic deterrents (ADDS, designed to deter seal s from aquaculture cages and fishing nets) operating at 10 kHz and 194 dB re 1 μ Pa will produce an avoidance response at 80m for harbour seals, 130m for bottlenose dolphins, 500m for harbour porpoises and 1,600m for killer whales. The DTI have recommended using the human value for safe distances for explosives of 600m for a 1kg explosive, 900m for 10kg and 2km for 100kg.

Given the proximity of the pipe construction operation to marine mammals and their foraging areas in the vicinity of Islandmagee and the Maidens rocks, great care should be taken to consider the potential noise levels and vibrations predicted to occur from any construction operations such as drilling or blasting. The proposed site lies not more than c. 2–3km from the area seaward of the Isle of Muck, where clusters of porpoise (and whale) sightings have been reported, and therefore physical aspects of the seabed and the fauna in this area – including the fish upon which the cetaceans feed – and the mammals themselves could all be adversely impacted by the construction works. However, with sensitive planning it should be possible to avoid serious or permanent damage to this area. The Maiden Rocks lie approximately 7–10 km from the outfall site and thus the seal haul-out sites and the cetacean feeding areas here probably lie outside the danger zone for mild or moderate explosions or vibrations at the construction site – but any risk should be carefully calculated once the physical properties of the construction process are fully known.

6.8.5.2 Operation Phase of Brine Outfall

Figure 6.14 and Figure 6.15 show the approximate location of the proposed brine outfall, which is currently expected to release the brine at about the 27m depth contour. As evident from Figure 6.15, the proposed outfall discharge point is c. 2–3 km to the NW of the porpoise feeding area. The hydrodynamic modelling of the brine plume, presented in detail in Chapter 9.0 "Coastal Processes" shows that the brine is dispersed rapidly, such that a dilution of >200:1 (36.6psu) is achieved at between 5m and 10m from the point of discharge. At the porpoise feeding area, the peak modelled increase in salinity across the tidal cycle will be less than 0.25psu and typical values will be even lower. These values are well within the normal variations to salinity experienced in the north channel and will not pose any adverse impact to cetaceans, their fish prey species and the distribution of benthic fauna at this site. A rigorous monitoring programme, which will be agreed with the NIEA prior to works commencing, will take place during the construction and operation of the brine outfall, to observe the measured outputs and impacts of the outfall and ensure that they are within those ranges predicted within the EIS.

With present information, it seems very unlikely that the brine outfall would have any impact on the cetacean foraging areas or on the seals in the vicinity of the Maidens Rocks, since the rocks are approximately 7–10 km from the proposed outfall site.

6.8.5.3 Residual Impacts on Marine Mammals

Following construction of the sea water intake and brine outfall structures, it is anticipated that the brine outfall will be in operation for a period of approximately four years. Subsequent to this, brine discharge will cease. The infrastructure will, however, remain in place in order facilitate maintenance of the caverns every 10-15 years. Discharges relating to maintenance will be subject to the same constraints and monitoring recommendations imposed for the initial leaching period and are therefore not anticipated to have any significant impacts on local seal and cetacean populations. However, it is recommended that pre-maintenance monitoring takes place of marine mammal populations to ensure that feeding areas remain outside the immediate influence of the brine outfall.

6.8.6 Plates Seal species, age and sex classes recorded during the Islandmagee Storage Project surveys



Plate 6.76 Subadult female grey seal at West Light



Plate 6.77 Adult female grey seals at West Light, 11/09/09



Plate 6.78 Adult male and female grey seal resting together on Alan Rock, 11/09/09



Plate 6.79 Juvenile common seal (left) and juvenile grey seal female (right) at West Light 12/07/09



Plate 6.80 Adult male grey seal at Russell Rock, 27/9/08



Plate 6.81 Two adult female grey seals and 1 pup seen on 02/11, at West Light



Plate 6.82 Unidentified seal seen on West Light, beside an adult male-female pair of grey seals (re-entered water due to approach of boat, 27/9/08



Plate 6.83 Adult common seal at West Light, 12/07/09



Plate 6.84 Adult female grey seal (left) and adult male common seal (right); Mill Bay, Larne Lough – 11/09/09

6.9 MARINE WATER QUALITY

6.9.1.1 The Water Framework Directive

In 2000 the European Parliament and Council adopted Directive 2000/60/EC (the Water Framework Directive). The Directive establishes the legal framework for the protection, improvement and sustainable management of inland surface waters, transitional waters, coastal waters and groundwater.

The Directive aims to provide a new, strengthened system for the protection and improvement of water resources and water-dependent ecosystems. It aims at preventing the deterioration in the existing status of waters, including the maintenance of "high status" where it exists, and at ensuring that all waters, with some limited exceptions, achieve at least "good status" by 2015.

Water Framework Directive Legislative Requirements

Article 4(1) of the Water Framework Directive sets out the environmental objectives or goals that must apply in relation to surface waters. Member States –

- must prevent deterioration in status
- 2. must protect high and good status waters where they exist
- 3. must restore waters of less than good status to at least "good status" by not later than 2015

Member States must implement the measures that are necessary to achieve these objectives. Measures must, for example, be put in place to control point source discharges liable to cause water pollution.

Member States must furthermore implement the measures necessary to progressively reduce pollution by priority substances, and also to cease or phase out emissions, discharges or losses of priority hazardous substances.

Current WFD Status

Larne Lough has been divided into three water bodies for the purposes of the water framework directive Figure 6.16.

Larne Lough North (Heavily Modified Water Body Larne Lough Mid Larne Lough South

The outfall is within the North Channel Coastal Water Body.

Larne Lough North's ecological classification has been determined as "good" status. Larne Lough Mid has failed, only achieving "moderate" status and Larne Lough South has also failed with "moderate" status. The North Channel's classification is "good".



Figure 6.16 Water Framework Directive Coastal Waterbodies

Potential Impacts

Increased morphological pressure leading to loss or complete removal of coastal habitats can cause a shift in the community structure from long lived perennial species to ephemeral, opportunist species which can dominate the community and restrict growth of other faunal and floral species. Excess suspended particulate matter increases turbidity leading to smothering and light limitation causing a dominance of tolerant macroalgae species.

The influence of the proposed brine discharge and its predicted impact on marine ecology has been examined in detail in Chapter 9 "Coastal Processes" and earlier in this chapter. It is considered that the brine discharge arising from leaching the caverns will have no significant impact on the local habitats and fisheries, beyond the immediate mixing zone. The brine discharge will not adversely impact the requirement to achieve or maintain the "Good Ecological Status" objectives outlined in the Water Framework Directive.

As discussed in Chapter 8, "Material Assets", the proposed development will not generate any additional nutrient input through its waste water discharges. The proposed development

will incorporate separate foul and storm water drainage systems. There is therefore no predicted impact