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WYLFA NEWYDD

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Wylfa Newydd Project

Horizon Nuclear Power Wylfa Limited

Subtidal Dive Surveys at the Cooling Water Outfall for the Existing Power Station

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Executive Summary

Jacobs UK Limited (Jacobs) was commissioned by Horizon Nuclear Power Wylfa Limited (Horizon) to undertake a full marine ecological survey programme within the vicinity of the proposed new nuclear power station (the Wylfa Newydd Generating Station) on north Anglesey. This report details the findings from subtidal dive surveys and intertidal quadrat surveys that were carried out in June 2015 to assess gradients in biodiversity with increasing distance from the Cooling Water (CW) outfall at the Existing Power Station.

Temperature is an important ecological parameter affecting many aspects of aquatic ecosystems. Elevated temperatures can influence community structure and diversity. Temperatures close to power station outfalls can be elevated by up to 12°C above ambient (depending on the station) and cause physiological stress and oxygen depletion. CW discharges are often expelled at high velocity resulting in potential mechanical stress on epibiota. The water may also contain anti-fouling biocide residues.

Since May 2012, the Existing Power Station on north Anglesey has operated only one out of two reactors (half-load) and therefore the rate of CW discharge has decreased by approximately 50% compared to the previous discharge rate of $70m^3s^{-1}$. Prior to complete cessation of operations, this provided a unique and final opportunity to repeat subtidal benthic surveys carried out in 2011 and 2012, though under different operational conditions. Intertidal benthic surveys carried out in 1987 and 2010 under full station operation, were also repeated during this period of reduced operation. The results have been used to determine whether any spatial changes have occurred in the intertidal and subtidal marine ecological communities along the receiving shoreline over the preceding three-year period (2012 to 2015) under the reduced operating regime.

The subtidal surveys used an approach based on the Marine Nature Conservation Review (MNCR) method to provide an accurate characterisation of the epibenthic communities and habitats. Study sites were located in the vicinity of the Existing Power Station and at locations further along the north Anglesey coast. The data obtained were then compared with those recorded from the same sites in 2011 and 2012.

In 2015 the subtidal surveys in the CW outfall channel, outfall bay and beyond demonstrated a clear, acute impact on the composition and structure of the shallow rocky reef communities within 100m of the outfall. Impacts of the CW discharge were clearly noticeable with algae as these were the dominant epibionts at most sites. Kelp species were absent within 100m and there were clear shifts in the dominant taxa within 150 -200m of the outfall. Densities of brown algae and red algae decreased close to the CW outfall in contrast to green algae which were recorded in higher densities. Subtle impacts were observed within approximately 250 – 300m of the CW outfall with differences in the dominant flora and fauna, although the overall diversity scores were comparable with those obtained at reference sites. The CW outfall did not appear to support a high abundance of non-native species. Although *Codium fragile*, *Asparagopsis armata* and *Heterosiphonia japonica* were recorded close to the outfall, the latter two species were also recorded at sites outwith the CW influence, often at greater abundances. *C. fragile* was recorded only as ‘rare’ in 2015. The outfall continued to attract large numbers of feeding bass, mostly within 100m of the discharge.

The intertidal quadrat surveys measured limpet and dog whelk abundance and percentage barnacle cover along the shore, up to 325m from the CW outfall. There was a decline in the abundance of dog whelks closer to the outfall with no individuals observed within 215m. This result might, however, have been limited by available physical habitat and, consequently, the exact points on the shore which were surveyed in any given year, as some dog whelks were observed at distances closer than this during the subtidal surveys. Limpets were recorded in lower abundances than in 2010 and 1987 with a clear decline closer to the outfall. As this relationship between limpet abundance and distance from the outfall has not been observed in previous years its exact cause is uncertain and may simply be an artefact of the sampling methods. Percentage barnacle cover fell noticeably with increasing proximity to the outfall. The results of the intertidal surveys corresponded with results from previous years although there were no changes that could be associated with a reduction in the Existing Power Station’s operating regime.

The ecological community data obtained during both intertidal and subtidal surveys in 2015 were almost identical to those obtained during full-load station operations in previous years. Therefore, it is considered that despite an approximate 50% reduction of CW discharge volume, the small bay receiving the outfall water most likely remains at, or near to, some level of physical carrying capacity for the discharged CW prior to it mixing in

the main tidal flow. The mixing with the strong currents around Wylfa Head then results in the rapid dispersal of the CW plume.

In conclusion, the surveys demonstrated a continued acute impact on the subtidal and intertidal, rocky reef communities within 100m of the CW outfall, with subtle effects extending to approximately 250-300m. Beyond these distances, there were no detectable differences in the ecological communities that were directly attributable to the CW outfall of the Existing Power Station.

1. Introduction

1.1 Overview

Horizon Nuclear Power Wylfa Limited (hereafter referred to as Horizon) is currently planning to develop a new nuclear power station on Anglesey as identified in the National Policy Statement for Nuclear Power Generation (EN-6). The Wylfa Newydd Project (the 'Project') comprises the proposed new Nuclear Power Station, including the reactors, associated plant and ancillary structures and features, together with all of the development needed to support its delivery, such as highway improvements, worker accommodation and specialist training facilities. The Project will require a number of applications to be made under different legislation to different regulators. As a Nationally Significant Infrastructure Project under the Planning Act 2008, the construction and operation must be authorised by a Development Consent Order.

Jacobs UK Limited (Jacobs) was commissioned by Horizon to undertake a full ecological survey programme within the vicinity of the proposed new nuclear power station on Anglesey (the Wylfa Newydd Generating Station). This work has included the gathering of baseline data to inform the various applications, assessments and permits that will be submitted for approval to construct and operate the Wylfa Newydd Generating Station and Associated Development[1].

In 2011 and 2012, *in situ* benthic surveys were carried out to determine the scale of any impacts on subtidal benthic communities around the existing Cooling Water (CW) outfall. Since May 2012 the Existing Power Station (operated by Magnox) has operated only one out of two reactors (half-load) and therefore the rate of CW discharge has decreased by approximately 50% compared to the previous discharge rate of $70m^3s^{-1}$. This report covers the findings of *in situ* benthic surveys that were carried out in June 2015 to determine any degree of spatial or temporal change on the intertidal and subtidal benthic communities since operation was reduced. As such this report functions as an addendum to the previous benthic reports and should be read in conjunction with those reports (Jacobs, 2015a; Jacobs, 2015b).

This report uses a number of technical terms and abbreviations. Key terms are capitalised and explained with their acronyms within the text.

1.2 The Wylfa Newydd Project

The Project includes the Power Station and Associated Development. The Power Station includes two UK Advanced Boiling Water Reactors to be supplied by Hitachi-GE Nuclear Energy Ltd, associated plant and ancillary structures and features. In addition to the reactors, development on the Power Station Site (the indicative area of land and sea within which the majority of the permanent Power Station buildings, plant and structures would be situated) would include steam turbines, control and service buildings, operational plant, radioactive waste storage buildings, ancillary structures, offices and coastal developments. The coastal developments would include a Cooling Water System (CWS) and breakwaters, in addition to a Marine Off-Loading Facility (MOLF).

1.3 The Wylfa Newydd Development Area

The Wylfa Newydd Development Area (the indicative areas of land and sea, including the Power Station Site, the Wylfa NPS Site[2] and the surrounding areas that would be used for the construction and operation of the Power Station) covers an area of approximately 409 ha. The Wylfa Newydd Development Area is bounded to the north by the coast and the Existing Power Station, whilst to the east it is separated from Cemaes Bay by a narrow corridor of agricultural land. The A5025 and residential properties define part of the south-east

[1] Development needed to support delivery of the Wylfa Newydd Generating Station is referred to as Associated Development. This includes highway improvements along the A5025, Park and Ride Facilities for construction workers, Logistics Centre, Temporary Worker Accommodation, specialist training facilities, Horizon's Visitor Centre and media briefing facilities.

[2] The site identified on Anglesey by the National Policy Statement for Energy (EN-6) as potentially suitable for the deployment of a new nuclear power station.

boundary, with a small parcel of land spanning the road to the north-east of Tregele. To the south and west, the Wylfa Newydd Development Area abuts agricultural land, and to the west it adjoins the coastal hinterland.

The Wylfa Newydd Development Area includes the headland south of Mynydd-y-Wylfa candidate local wildlife site. There are two designated sites for nature conservation within the Wylfa Newydd Development Area: the Tre'r Gof Site of Special Scientific Interest (SSSI) and the Anglesey Terns/Morwenoliaid Ynys Môn Special Protection Area. There is also a candidate Special Area of Conservation (cSAC) that has been submitted to the European Commission, but not formally adopted (North Anglesey Marine/Gogledd Môn Forol cSAC). The Wylfa Newydd Development Area is within 1 km of the Cae Gwyn SSSI, Cemlyn Bay Special Area of Conservation (SAC) and SSSI[3].

The open coast location of the Existing Power Station is characterised by strong tidal flows (>1.5ms^{-1}) and a seabed that slopes steeply to a depth of approximately 25-30m. The substrata are comprised of a mix of bedrock, boulders, cobbles and sediments, including gravel and sands in variable proportions. The infralittoral coastline around The Existing Power Station comprises a diverse habitat assemblage characteristic of a moderately exposed, western UK rocky coastline and is dominated by macrophytic algae.

1.4 Background

The CWS technology to be adopted for the Project has yet to be determined but the preferred option for maximising plant efficiency is direct cooling which would require seawater extraction from and discharge to the local environment. The Power Station would generate a greater thermal output both in terms of heat and volume compared with the Existing Power Station and the potential impacts on the marine environment must be considered.

The Existing Power Station is designed to operate with a CWS temperature rise of up to 10.3°C ΔT (ΔT = above ambient water temperature) and to discharge CW at 70m^{3}s^{-1} (i.e. 70 cumecs). However, since operating with a single reactor on a permanent basis commenced in May 2012, the CWS has been discharging at approximately 35m^{3}s^{-1}, although the temperature rise across the CWS has not changed. There have also been periods of outage associated with reactor maintenance and given that only a single reactor has been in use, this has resulted in occasional and variable periods without any thermal output. Information on station operation provided by Magnox, indicated that since April 2012 there have been three main outage periods: from early October to mid-November 2012; from early January to the end of June 2014; and from early March to early April 2015.

Temperature is an important ecological parameter affecting many aspects of aquatic ecosystems. Elevated temperatures can influence community structure and diversity but the impacts at any one site can be hard to predict owing to the many variables involved, e.g. quantity of heat discharged, dispersal of heated water, physical environment affected and species-specific temperature tolerances. Temperatures close to the Existing Power Station outfall can be elevated by up to 10.3°C ΔT which could cause physiological stress to organisms as a result of increased metabolic rate and/or oxygen depletion. CW discharges may also contain biocide residues and the velocity of the expelled water can give rise to elevated mechanical stress in some instances (e.g. Bamber, 1991; Teixeira *et al*., 2012).

1.5 Study aims and objectives

Given the changes to the Existing Power Station's operating regime as outlined above, this report aimed to repeat previous subtidal and intertidal surveys of the ecological communities around the CW discharge which were originally carried out under full load operations. The objective of these surveys was to determine whether or not over the preceding three-year period of reduced operation (2012 to 2015), any changes had occurred in the ecological communities that might be associated with a reduction in discharged CW volume.

1.6 Survey description

In 2015, diver surveys were carried out on the subtidal epibenthic habitats around Wylfa Head and along the north coast of Anglesey to assess gradients in biodiversity with increasing distance from the Existing Power

[3] Note that the names of designated and conservation sites used throughout the report are consistent with JNCC guidance.

Station CW outfall. Intertidal quadrat surveys were also carried out at increasing distances from the outfall to determine gradients in abundances of specific taxa (barnacles, limpets and dog whelks).

This report presents the diving survey work completed in 2015 and has considered spatial and, more specifically, temporal comparison of the associated benthic assemblages with those reported in 2011 and 2012. The intertidal data are also reported and comparisons made with results obtained using the same methods in 1987 (Bamber, 1989) and 2010 (Jacobs, 2015b). This report forms part of the ongoing work to gather ecological data to inform the Environmental Statement and Habitats Regulations Assessment for the Project.

2. Methodology

2.1 Subtidal surveys

2.1.1 Field survey logistics

The survey was carried out from 20th - 26th June 2015, with a view to encompassing neap tides as much as was feasible (see Appendix A).

The diving operations were led by Marine Ecological Solutions Limited, a specialised diving contractor. All diving operations were carried out in accordance with the Health and Safety Diving at Work Regulations 1997 (DWR 97) and the ACOP L107 Approved Code of Practice for Scientific and Archaeological Diving Projects. The dive survey team comprised one supervisor, one competent technical assistant, four marine ecologists and the boat skipper. All diving was carried out using open-circuit scuba equipment with an independent alternate air source.

2.1.2 Site location and fixes

All site locations targeted the same locations as those used for the *in situ* benthic surveys of 2011 and 2012 with the exception of those at Point Lynas (Table 2.1, Figure 2.1 and Figure 2.2). The pre-selected sites were located using a boat-mounted GPS. Once the divers were in the water, the GPS was then used to take an accurate fix of the transect start positions. In addition to this, many of the dives had a GPS fixed to the divers' surface marker buoys, allowing a continual fix on their position.

The GPS fixes were recorded on the diving log and the waypoints were later downloaded into MapInfo files and imported into a GIS database. All positions were derived from the GPS and given in World Geodetic System (WGS) as WGS84 co-ordinates (see Appendix A).

Table 2.1: Benthic sites surveyed in 2015 (Outfall Channel (BG), Outfall West (OW), Outfall East (OE), Llanbadrig (LB), Wylfa Head (WH) and Point Lynas (PL)) and a summary description. All sites, with the exception of PL, were also surveyed in 2011 and 2012.

Site Name	General Location	Reason for Selection
BG1 (split into sites BG1S3-5 to remain consistent with BG1S3-5 in previous outfall surveys)	**Outfall Channel** 20-80m from outfall point on the west side of the channel.	Selected during surveys to provide a further understanding of the community changes being recorded.
OW1-OW4	**Outfall West** 100-320m from the outfall and to the west.	Pre-selected to provide data on community-level impacts near to the outfall.
OE1-OE4	**Outfall East** 140-330m from the outfall and to the east.	Pre-selected to provide data on community-level impacts near to the outfall.
WH1-WH3	**Wylfa Head** 465-645m from the outfall on the north of Wylfa Head.	Pre-selected to provide data on any community-level impacts further from the outfall in the main tidal stream.
LB1-LB6	**Llanbadrig** 2.8-3.3km to the east of the outfall at Llanbadrig.	Reference sites. LB1-LB3 are sheltered from strong natural currents, as would be the outfall BG, OW and OE sites. LB4-LB6 are exposed to stronger currents, as at Wylfa Head.
PL1-PL2	**Point Lynas** Approx. 13km to the east of the outfall.	Alternative reference site. This was surveyed following discussions with NRW to determine the potential for this site to be used as a longer term reference site for monitoring work.

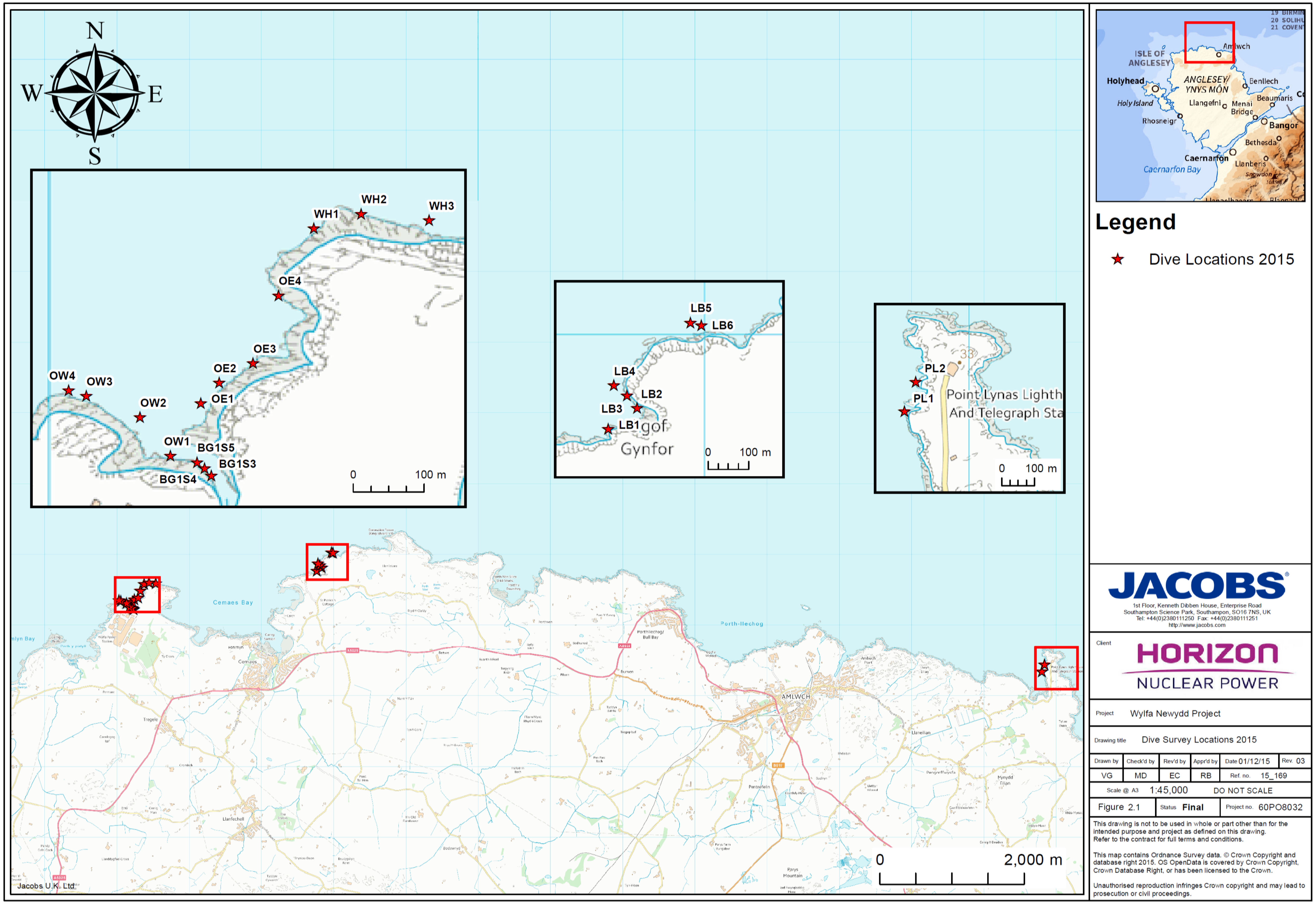


Figure 2.1: Location of survey sites in the cooling water Outfall Channel (BG), Outfall West (OW), Outfall East (OE), Llanbadrig (LB), Wylfa Head (WH) and Point Lynas (PL) in 2015.

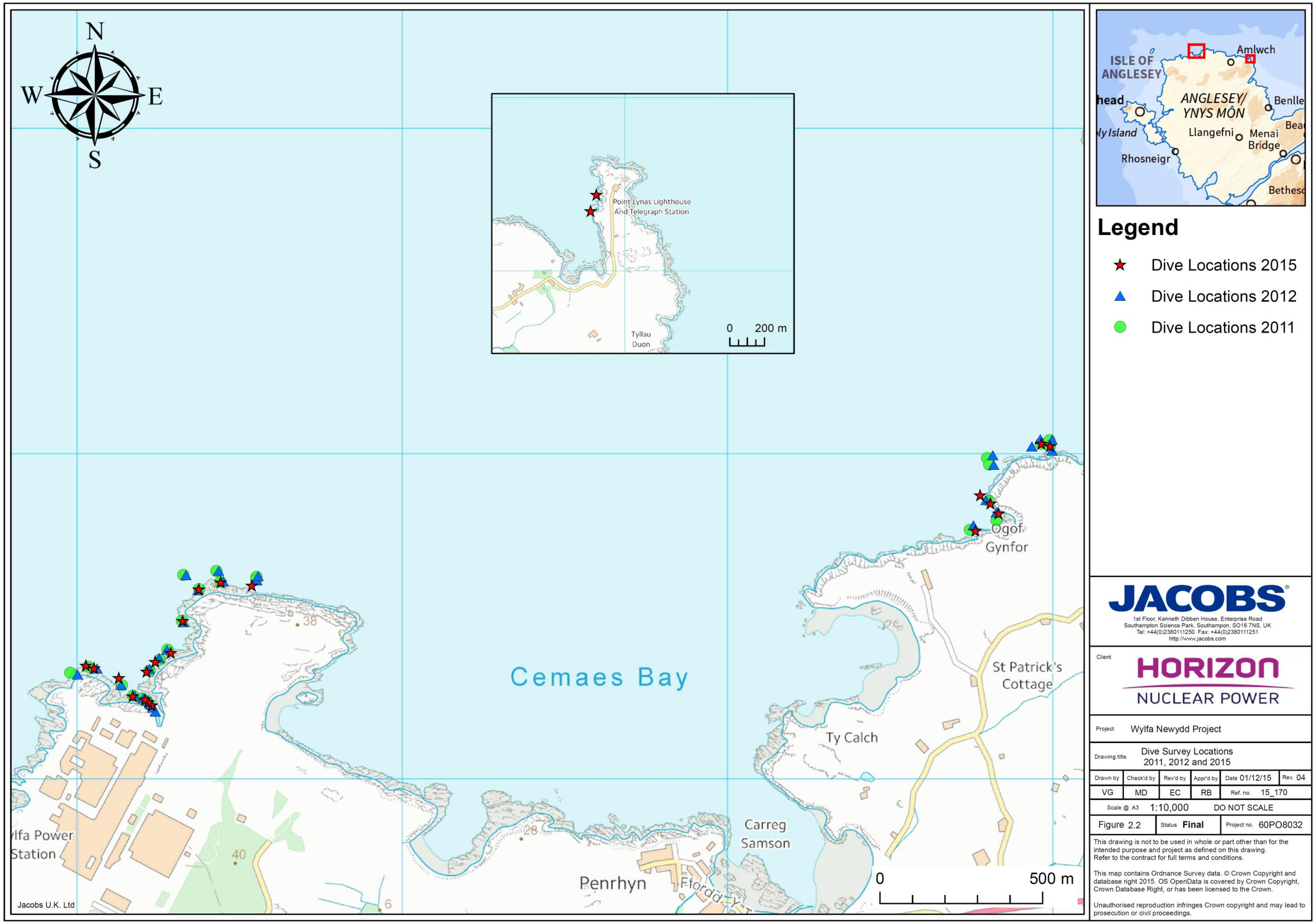


Figure 2.2: Location of survey sites in the cooling water in 2011, 2012 and 2015.

2.1.3 Survey methodology

All survey methods used for this work matched those used in the 2011 and 2012 surveys (Jacobs, 2015a) the report on which should be referred to for further information on the methodology. The 2015 surveys were carried out from the RIB 'Interceptor'.

It should be acknowledged that the 2015 survey did not attempt to characterise circalittoral communities, and instead concentrated on the shallower infralittoral habitats only. This approach was based on the discharged cooling water being buoyant in nature with effects previously only being detectable on the infralittoral communities. Furthermore, the shallow nature of the sites close to the outfall (BG, OW and OE sites) meant there was a lack of options for comparable deeper transects at these sites.

Appendix B gives the Marine Nature Conservation Review (MNCR) abundance scales (SACFOR[4]) used to estimate abundance of conspicuous taxa identified *in situ*. Further appendices which are pertinent to the survey methodology and data analysis can be found in Jacobs (2015a); these include a selection of photographs to show habitat characteristics and also information on the statistical analyses. Raw data from the 2015 surveys are provided in the CD Appendix.

In addition to recording the general features of each site, a single MNCR sublittoral habitat form was completed and quality checked for each habitat encountered within the 30m transect. Descriptions for each habitat (physical and biological, National Marine Biotope Classification (Connor *et al*., 2004)) were recorded along with the quantitative biota data (Appendix C and CD Appendix respectively). The distance of each transect from the outfall is provided in Appendix D with comparative distances for the sites surveyed in 2011 and 2012. A maximum of two habitats were recorded at each site. Each transect took approximately one hour to survey. Taxa that were difficult to identify *in situ* were, where possible, retained for later identification. Photographs were taken at most sites to illustrate the habitats and communities present. Poor visibility at some of the sites meant photographs were not obtained for every habitat recorded.

2.1.3.1 Deviations from standard survey methodology

If during the course of the surveys, marked step-changes in community composition was observed at spatial scales of less than 30m, the transects was subdivided and in some cases reduced in length. This deviation allowed acute, linear effects, which would have otherwise been missed if only a standard 30m transect were used, to be captured within the data set for further analysis. Instances where transect lines were subdivided and/or shortened is clearly outlined in section 3 of this report.

2.1.4 Data management and analysis

A MNCR recording form was used for each habitat at all of the sites, with typically two habitats being found at each site. Each habitat was given a reference which was formed of the site name, e.g. 'LB4'; a letter 'S' to denote a 'shallow' survey and a further number at the end referring to the habitat. For example 'LB4S2', is the second shallow habitat of the Llanbadrig '4' site. Most dives were approximately 0-6m below chart datum (bcd) (depending on the tidal state) just below the kelp line in the infralittoral zone. Although some habitats were recorded as extending above chart datum, these were often at the extreme low water mark meaning exposure at low water would only occur during extreme low-tide events and they likely remained submerged for the most part.

A taxa list was created by combining all taxa found during the 2015 survey and excluding any entries that might not represent discrete taxa e.g. where a taxon could potentially have been recorded within a higher taxonomic group, such as family or order, already listed (Appendix E). An abundance data matrix was produced in Excel using the SACFOR data (see Appendix B). Where data were compared across all years, the spreadsheets were combined within PRIMER™ 6.1.11 (Primer-E Ltd, Plymouth) and a matrix produced that contained all the data for all three survey years (2011, 2012 and 2015). The taxa lists were then cross-checked for consistency and

[4] The SACFOR scale of abundance is a scale of cover/density scales which provide a unified system for recording the abundance of marine benthic flora and fauna in biological surveys (JNCC, 2006).

any further merging of taxa (from different taxonomic levels) was undertaken to prevent the possible repetition of taxa across different taxonomic levels in the analysis.

SACFOR ratings for each taxon were assigned a numerical equivalent using guidance from the Mapping European Seabed Habitats project (MESH, 2012); an equivalent of a log(x+1) transformation was used. The average abundance for the site across habitats was then calculated for each taxon at each site. Any averaged values less than 1 (except those represented by ‘present’) were assigned a value of 1 to indicate ‘rare’. The abundance data matrix excluded taxa that did not necessarily represent additional species for each site surveyed (e.g. unidentified juveniles) (see CD Appendix).

The univariate measures of total abundance (N) and taxa richness (S) were calculated as was the Shannon-Wiener index (H’) using PRIMER™. It should be noted that the figures for total abundance (N) are based on the averaged SACFOR abundances for each site (which are based on the equivalent of a log(x+1) transformation as detailed above) and do not represent actual abundance counts for each taxa. However they are presented in the results as an indication of overall biotic abundance at each site. Many of the taxa present were colonial and these, along with most algae, do not lend themselves to conventional abundance estimates.

Similarity and potential grouping of sites was examined by non-metric Multi-Dimensional Scaling (MDS) of the converted SACFOR data using the Bray-Curtis coefficient of similarity and the PRIMER™ statistical package. The MDS ordination provided a 2-dimensional and 3-dimensional representation of similarities between samples, i.e. the more similar a community sample was to another, the closer they appeared on the MDS plot.

Cluster analysis was also used to detect groupings of samples, such that samples within a group were more similar to each other than samples between groups. The result of hierarchical clustering was represented by a dendrogram. A Similarity Profile (SIMPROF) test was carried out to search for statistically significant evidence (at the 5% significance level) of genuine clusters in the samples. SIMPROF tests the statistical validity of each group at every node of the dendrogram. Significant groupings were highlighted in red.

2.2 Intertidal quadrat surveys

To determine any changes in populations in the immediate proximity of the Existing Power Station outfall under conditions of reduced station operation, the work described by Bamber (1989) was repeated. This involved the study of populations of dog whelks (*Nucella lapillus*), barnacles (Cirripedia spp.) and limpets (*Patella* spp.) to the west of the outfall. The populations were sampled at low water at ten stations located at 10m, 25m, 40m, 55m, 105m, 125m, 215m, 255m, 280m and 325m from the outfall. These stations were along the same stretch of coastline as the Outfall Channel (BG) and Outfall West (OW) sites described above for the subtidal surveys (Figure 2.1).

For dog whelks and limpets the number of individuals present within five replicate 0.25m^2 quadrats was recorded, while for barnacles the percentage cover was recorded within five replicate 0.01m^2 quadrats. The latter used the original method (Bamber, 1989) to enable comparison of the data from all years, whereby the number of grid cells containing barnacles were counted and this figure used directly as percentage cover. Distance from the outfall was determined using a combination of a tape measure and a GPS unit depending on the nature of the coastline and the ease of deploying the tape measure.

Data were presented as simple graphical representations of changes in numbers / percentage cover (+/- standard deviation) with distance from the Existing Power Station’s CW discharge point. *T*-tests were carried out (Excel data analysis) where differences between the numbers recorded in different survey years were apparent.

3. Results

3.1 Subtidal dive surveys

Table C1 (Appendix C) lists the habitats and number of taxa recorded from the 20 shallow sites in 2015 and is followed by descriptions of each habitat surveyed at each site. The distance of the centre point of each site from the outfall in each survey year is provided in Appendix D.

3.1.1 Site descriptions and biotopes

Detailed site descriptions and biotopes for all locations surveyed are provided in Appendix C. Sites close to the CW outfall (<100 m) did not accurately match any of the pre-defined, JNCC biotope codes owing to the impact of the heated discharge water (see Jacobs, 2015a); the JNCC biotope classification system does not generally account for anthropogenic disturbances. In the instances of impacted habitats, higher level codes were applied to account for the physical environment and a description of the biological communities was provided.

3.1.2 Water temperature

Water temperatures recorded on dive computers during the 2015 survey period indicated that ambient seawater temperatures along the north Anglesey coast were in the region of 13°C. Closer to the outfall (sites OW, OE and BG) elevated temperatures in the upper water column (top 4–5m) were frequently encountered, registering up to 20°C at BG. The influence of the heated cooling water varies with tidal state at many of the survey sites. Despite the Existing Power Station operating at a reduced load, the temperature rise throughout the CWS remained the same, only the volume discharged was reduced.

3.1.3 Community composition overview

The minimum taxa richness across all survey sites totalled 264 in 2015. This compared well with the taxa numbers recorded in the 2011 and 2012 surveys, from the shallow survey sites only, with values of 245 and 255 respectively, for minimum taxa richness.

In 2015, the total number of taxa per shallow water transect (no deep transects were done in 2015) ranged between 10 (BG1S4) and 106 (PL1 and PL2). This compared well with data from shallow transects in previous surveys (4–101 in 2011; 1–103 in 2012). Although the sites from Point Lynas (as done in 2015) were not included in the 2011 and 2012 surveys, they supported similar communities to those at Llanbadrig and Wylfa Head. Most habitats surveyed were within the upper and lower infralittoral and comprised of kelp forest or park with an understorey dominated by red algae. Where kelp species were absent, red algae remained common but faunal turfs of sponges, hydroids, bryozoans, anemones and tunicates often increased.

The most commonly recorded (>90% occurrence) brown algae throughout the survey were the kelp, *Laminaria hyperborea* and the branching species *Dictyota dichotoma*. Dominant red algae included coralline crusts, *Corallina officinalis*, *Schottera nicaeensis*, *Plocamium* spp., *Heterosiphonia plumosa*, *Rhodymenia pseudopalmata*, *Cryptopleura ramosa*, *Delesseria sanguinea*, *Phyllophora pseudoceranoides* and *Erythroglossum laciniatum*. Green algae, *Cladophora* spp. were also recorded at most sites. Abundant fauna across the sites were barnacles, bryozoans (*Electra pilosa* and ‘indeterminate (indet.). crusts’), the sponge *Sycon ciliatum* and the tunicates *Aplidium punctum* and *Clavelina lepadiformis*.

Sponges and hydroids were notable by their absence from BG1S3-BG1S5 and OW1. Bryozoans and tunicates were also absent from BG1S3- BG1S5 but *Electra pilosa* and *Clavelina lepadiformis* were recorded at OW1.

The biota recorded in 2015 were represented by 15 distinct taxa groups split into either phyla, order or class. In all years, survey records were dominated by the phylum Rhodophyta (red algae) which accounted for approximately 20% of the total number of taxa (Table 3.1). More than 60% of the species recorded in all years were represented by only five taxa groups: Rhodophyta, Cnidaria, Porifera, Mollusca, and Tunicata. A list of the taxa recorded during the 2011 and 2012 surveys, when the station was at full operation, is provided in the previous outfall survey report (Jacobs, 2015a). Whilst a taxa list covering all taxa recorded in 2015 is provided in Appendix E.

Table 3.1: Composition of rocky reef taxa recorded from all shallow survey sites in 2011, 2012 and 2015.

Taxa group	No. of taxa			Percentage Composition (%)		
	2011	2012	2015	2011	2012	2015
Platyhelminthes	1	1	1	0.4	0.4	0.4
Nemertea	1	0	0	0.4	0.0	0
Pycnogonida	1	1	1	0.4	0.4	0.4
Phoronida	1	1	1	0.4	0.4	0.4
Chlorophyta	4	7	8	1.6	2.7	3.0
Echinodermata	11	11	12	4.5	4.3	4.5
Annelida	12	6	9	4.9	2.4	3.4
Bryozoa	15	21	16	6.1	8.2	6.1
Ochrophyta	16	20	14	5.3	7.8	5.3
Pisces	14	10	11	4.9	3.9	4.2
Crustacea	13	15	15	4.9	5.9	5.7
Tunicata	25	24	23	10.2	9.4	8.7
Cnidaria	24	30	35	9.8	11.8	13.3
Mollusca	26	27	24	10.2	10.6	9.1
Porifera	35	31	33	13.5	12.2	12.5
Rhodophyta	57	50	61	22.4	19.6	23.1

3.1.4 Data analyses

To examine impacts from the CW discharge, composition data from the shallow transects were analysed in PRIMER^{TM}.

3.1.4.1 2015 data

As in previous years, a number of considerations should be borne in mind when viewing the data outputs from the surveys. At BG1S3 and BG1S4 (approximately 35m and 50m from the outfall respectively) the surveyors were only able to hold position for approximately 10 minutes at these distances owing to the strong flow of the water. A total of 16 and 10 taxa were recorded at BG1S3 and BG1S4 respectively.

The BG transects were also shorter in length than the other site transects. This was as per the previous surveys and reflects the acute, linear step-changes in community composition observed at the BG sites. The approach of splitting the data into these smaller, higher-resolution spatial scales is warranted to reflect the rapid biotic changes with distance within the CW outfall channel which were not observed within the other sites. These rapid step-changes would be missed if only the standard 30m transects were used.

Cluster analysis using SIMPROF significance testing indicated that the survey sites closest to the CW outfall (BG1S3-BG1S5) formed a distinct cluster with 54% similarity to one another and only a 19% similarity in community composition with any of the other sites (Figure 3.1). The next closest sites to the CW outfall (OW1 and OW2) showed no significant similarities (p>0.999) to any other sites and were only 38% similar to one another. The remaining sites were all at least 51% similar to one another although several distinct clusters (shown in red) were identified within this main grouping. However, there was no distinct spatial pattern to these remaining clusters with individual sites from each of the General Locations being grouped together. The only consistent clustering within any General Location was of all three Wylfa Head (WH1–WH3) sites, albeit along with LB1 and PL2. This seemingly random clustering of sites suggested few discernible ecological differences between any of the General Locations surveyed i.e. OW3 and OW4, OE, WH, LB and PL sites, with the exception of BG1 (BG1S3 – BG1S5) and OW1 and OW2. Further examination of these community similarities and differences follows below.

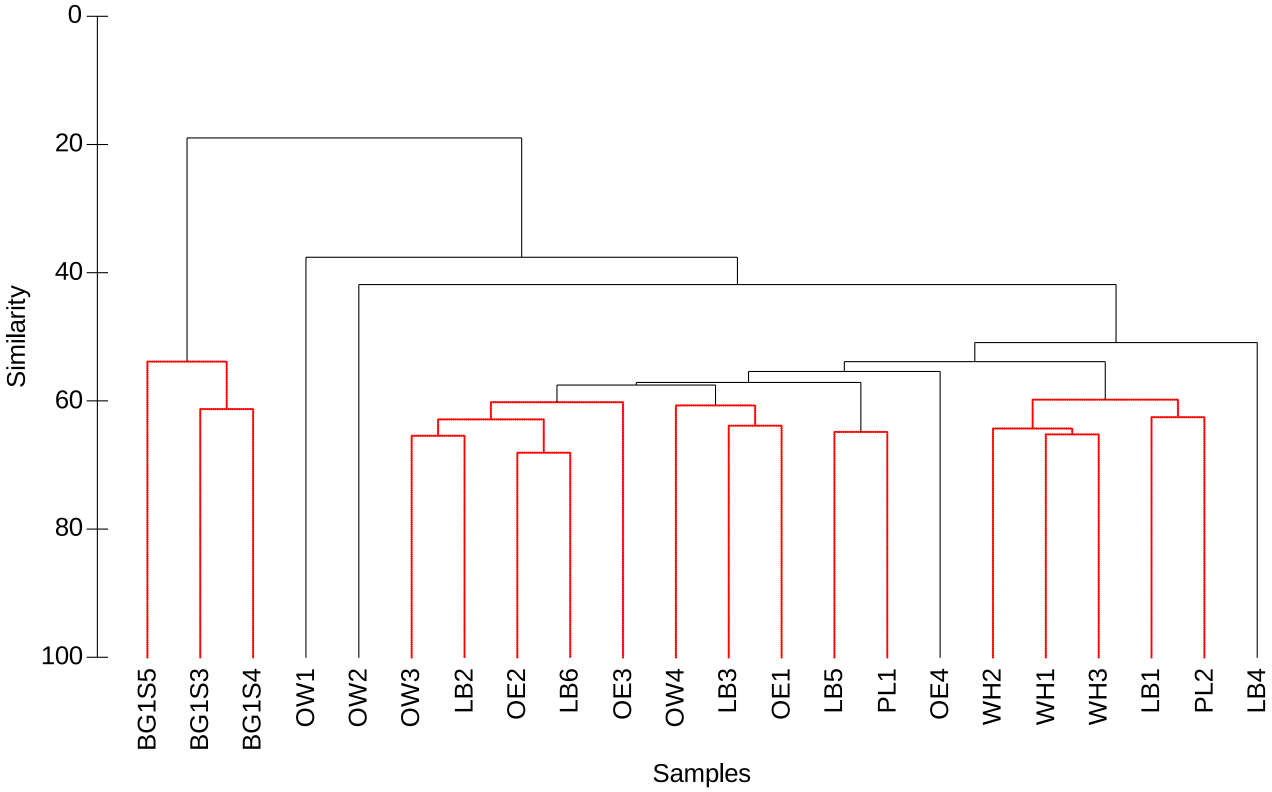


Figure 3.1: Cluster analysis and SIMPROF significance testing of shallow transect surveys (joined red lines indicate significant clusters, $p<0.05$) surveyed in 2015.

Spatial patterns in community composition were also illustrated in the MDS plot (Figure 3.2) which showed clear separation of the closest sites to the CW outfall (i.e. BG1S3 – BG1S5, OW1 and OW2) from the remaining sites. The sites then show greater similarity to one another with increasing distance from the outfall, particularly the Llanbadrig sites with the OE, OW3 and OW4 sites.

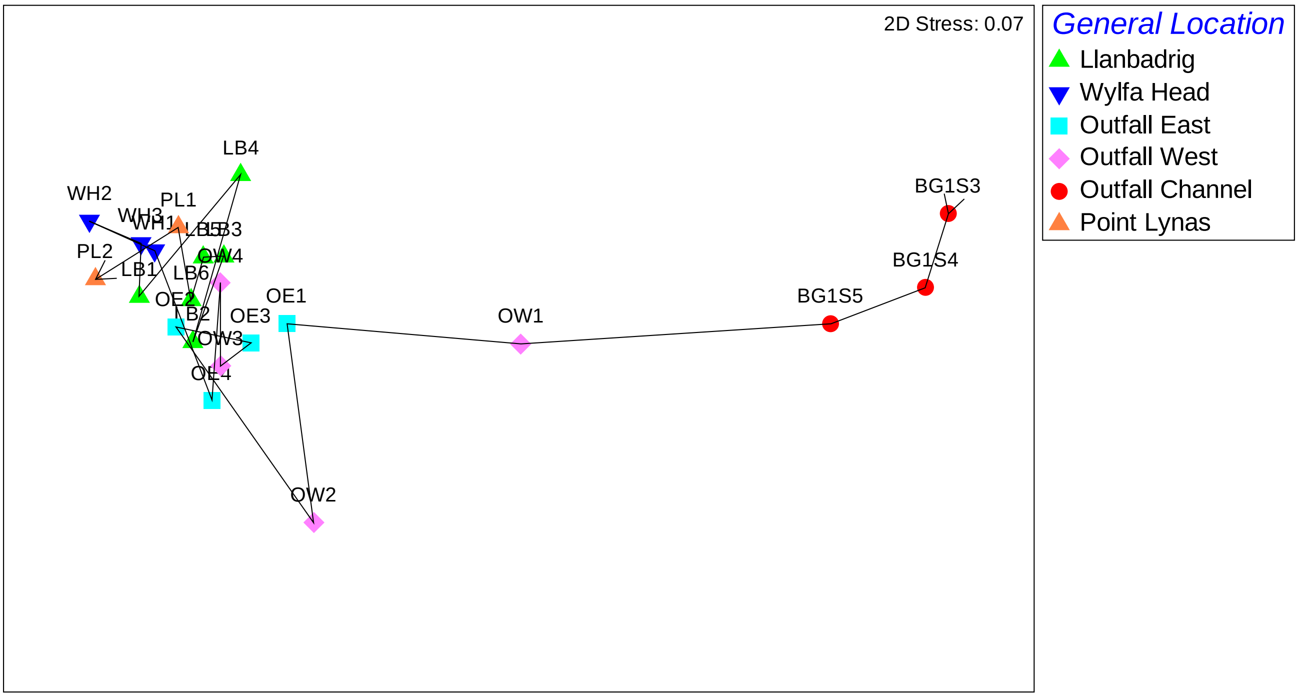


Figure 3.2: MDS plot of shallow transect sample data at sites with increasing distance from the CW outfall at the Existing Power Station in 2015. Sites were denoted as Outfall Channel (BG), Outfall West (OW), Outfall East (OE), Llanbadrig (LB), Wylfa Head (WH) and Point Lynas (PL).

When viewed in closer detail on the 3-dimensional MDS plot (Figure 3.3) with the exclusion of sites BG1S3 – BG1S5 and OW1 and OW2, the remaining sites show some subtle differences between the more distant and reference sites i.e. Wylfa Head, Llanbadrig and Point Lynas. However, in general the sites from Llanbadrig (LB) appear most similar to the OE and remaining OW sites than the closer Wylfa Head (WH) and more distant (and probably more wave surged[5]) Point Lynas (PL) sites.

[5] Based on field observations of the intertidal and upper infralittoral communities.

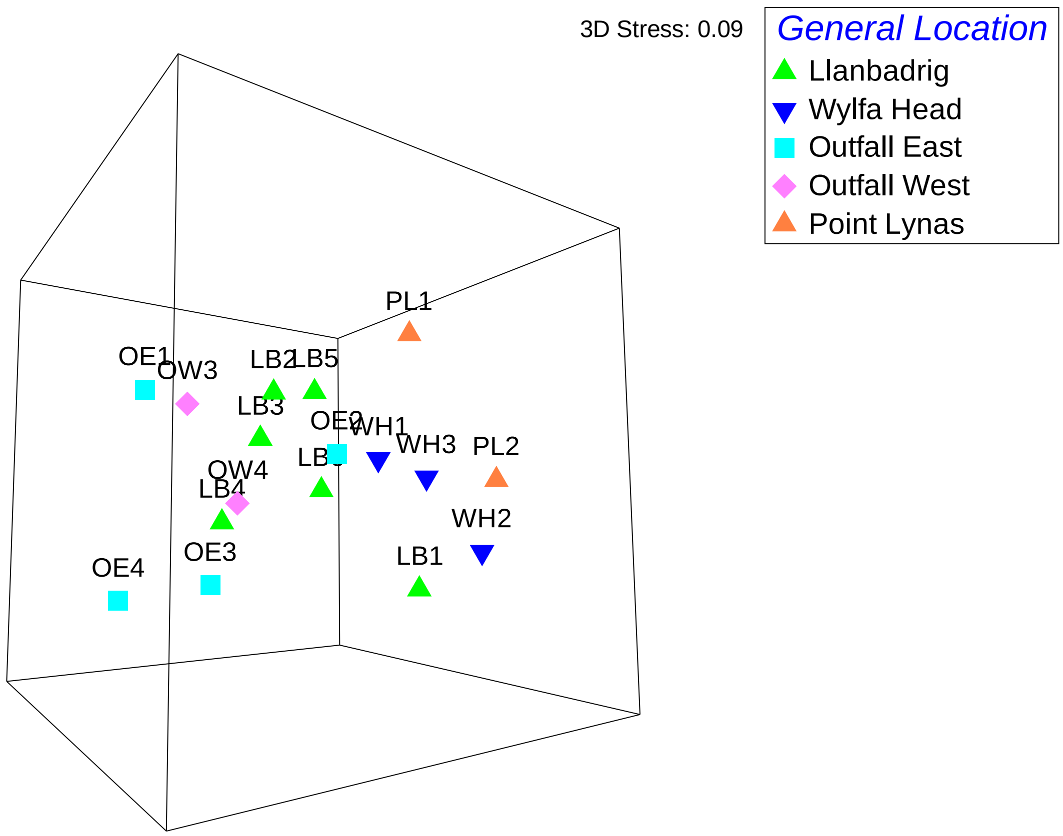


Figure 3.3: 3-dimensional MDS plot of shallow transect sample data at sites surveyed with increasing distance from the CW outfall at the Existing Power Station in 2015. Sites BG1S3 – 5 and OW1 and 2 have been removed to permit better spatial comparisons. A 3-dimensional plot was used as it provided a better representation of the data (low stress value).

Univariate measures showed a similar pattern to that derived from multivariate analyses. The number of species (S) fell markedly within ~200m to the west of the outfall (OW sites) whilst changes to the east (OE sites) were less distinct from sites further afield using this form of analysis (Table 3.2). The general increase in taxa with increasing distance from the CW outfall appeared to reach stable values, comparable to 'reference' sites, at around 200m to 280m from the outfall depending on whether the sites in question were to the east or west respectively (chart A, Figure 3.4). The exception to this could be the lower number of taxa recorded at OE4 although this might be due to site conditions on the day as in 2011 this site also had a lower number of taxa recorded (S=66) but a higher number in 2012 (S=82). The Shannon Wiener index (H'(log_e)) (Table 3.2; charts B and C Figure 3.4) shows a clear asymptotic relationship (progress toward a constant number) of increasing diversity with distance from the outfall. The diversity index is based on overall SACFOR scores for each site rather than actual raw abundance data, and therefore caution should be applied with these values. However, the positive relationship, of distance from the outfall with diversity, remains clear.

Table 3.2: Univariate measures of number of taxa (S), total abundance (N) (based on assigned SACFOR scores of 1 – 6 (0.3 for 'present')) and Shannon Wiener diversity index (H'(log_e)) for transects at increasing distance from the CW outfall at the Existing Power Station in 2015.

Distance from CW outfall (km)	Site	S	N	H'(log_e)
0.031	BG1S3	16	30	2.541
0.051	BG1S4	10	30	2.052
0.067	BG1S5	22	40	2.914
0.101	OW1	51	66	3.807
0.139	OE1	69	101	4.114
0.172	OW2	48	81	3.705
0.176	OE2	100	127	4.525
0.233	OE3	91	109	4.422
0.246	OW3	83	105	4.317
0.277	OW4	69	95	4.125
0.338	OE4	54	82	3.876
0.466	WH1	93	124	4.423
0.536	WH2	99	145	4.445
0.625	WH3	104	145	4.531
2.900	LB1	81	119	4.247
3.000	LB2	90	104	4.450
3.000	LB3	80	114	4.249
3.000	LB4	69	100	4.064
3.200	LB5	97	130	4.468
3.300	LB6	92	119	4.436
13.500	PL1	105	153	4.545
13.500	PL2	105	129	4.577

Overall, a sharp increase in the Shannon Wiener diversity index with increasing distance from the CW outfall was apparent up to 200m, where the diversity then appeared to plateau, despite there being some small fluctuations thereafter up to a distance of 350m (Figure 3.4). Beyond 170m, the remaining OW and OE sites had Shannon Wiener diversity values consistent with those at Wylfa Head and the reference locations at Llanbadrig and Point Lynas.

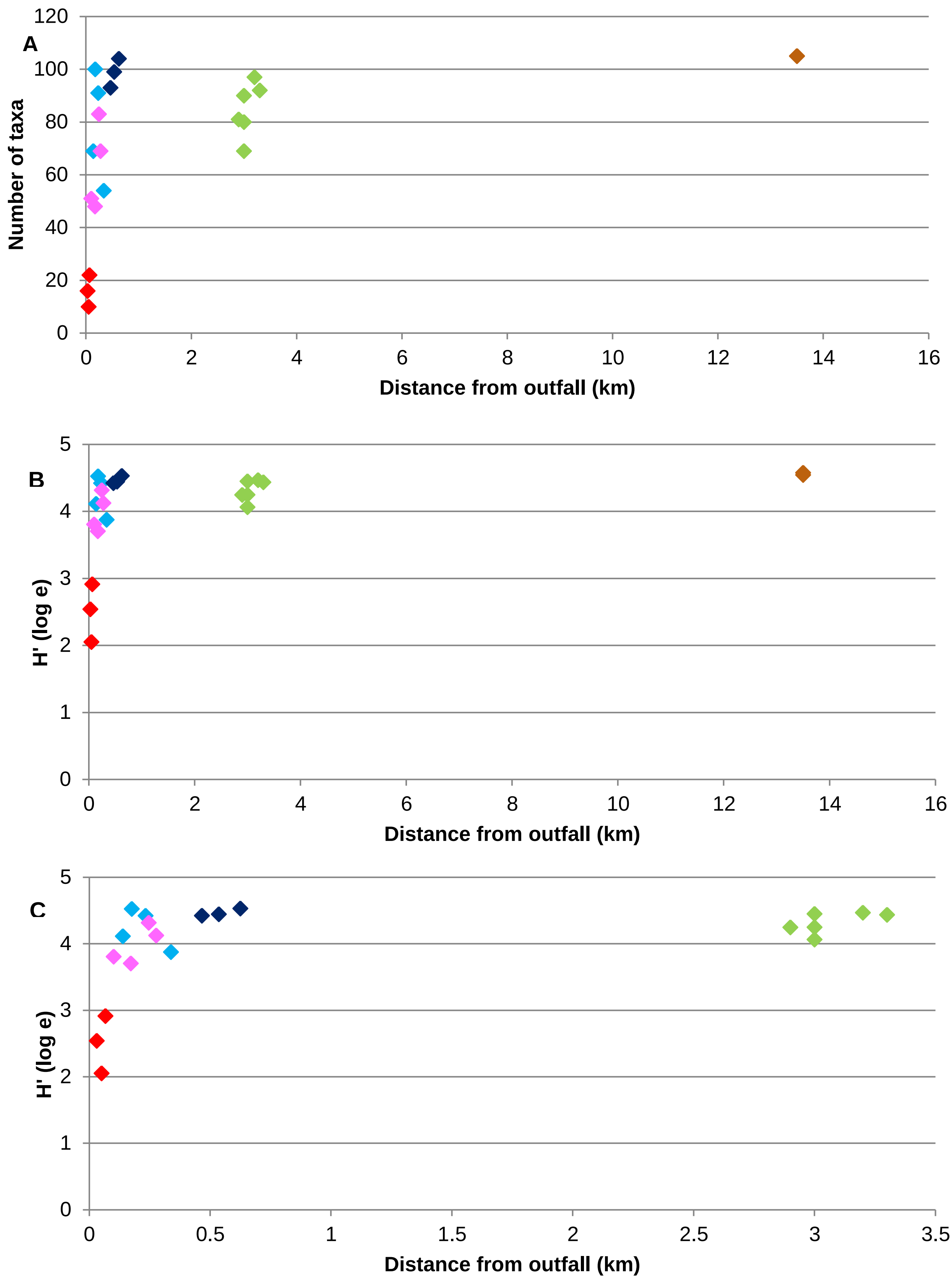


Figure 3.4: Number of taxa (A) and diversity index (B and C) recorded during shallow transect surveys with increasing distance from the CW outfall at the Existing Power Station, north Anglesey in 2015. Chart C is a repeat of chart B with Point Lynas sites excluded to show the values more clearly close to the outfall. Colours represent site General Locations (red=Outfall Channel (BG sites)), pink=Outfall West, turquoise=Outfall East, dark blue=Wylfa Head, green=Llanbadrig, orange=Point Lynas).

3.1.4.2 All years data – 2011, 2012 and 2015

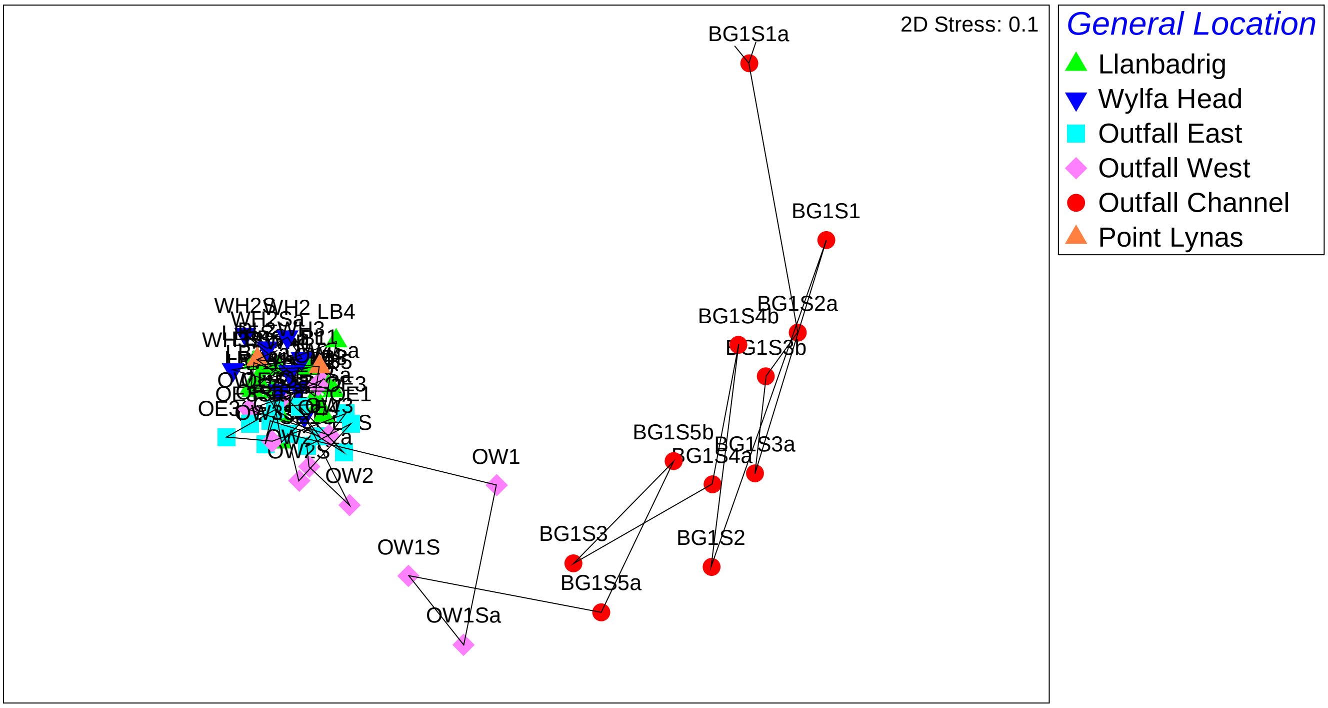
When the community assemblage data for all years were combined, a pattern similar to that shown by the data sets for each individual year (Jacobs, 2015a) was given by an MDS plot (Figure 3.5). In terms of community composition the BG sites and OW1 and 2 showed a clear gradient of change toward the main cluster of sites from all years. The BG sites and OW1 and 2 were quite separate from the other sites, highlighting differences in composition, though the tight clustering of all the other samples made any spatial or temporal differences between the clustered samples hard to determine. To examine the relationships between samples in the remaining sites, the MDS plots were redrawn with the BG sites and OW1 excluded (Figure 3.6). It was then apparent that within this main cluster, there was a degree of separation of the OW and OE sites from the WH and PL sites with the LB sites overlapping both (Figure 3.6A). When displaying the data based on survey year however it was clear that samples from within each year were also more tightly clustered than samples between years suggesting a small degree of temporal variation (Figure 3.6B). To examine these spatial and temporal differences further, a cluster analysis was carried out.

Cluster analysis (with SIMPROF) of the combined data sets showed a very obvious clustering of the BG sites and OW1 on the left-hand side of the plot away from all the other sites, having only 19% similarity with them (Figure 3.7). Within this cluster, the OW1 data from all years and BG1S5 from 2012 (one of the furthest BG sites from the outfall) also showed a distinct clustering away from the other BG sites, illustrating the sharp gradient of change in communities closer to the outfall. In 2012 the site BG1S1, which was the closest location ever surveyed to the outfall, showed only 7% similarity to any other sample, most likely only to the presence of coralline encrusting algae and barnacles.

In the second main grouping, to the right hand side of the plot, any spatial patterns were harder to discern. Several significant clusters of samples were identified by the SIMPROF test but many contained samples from different General Location. As a general rule, samples from Wylfa Head were more frequently clustered, albeit loosely, to the right-hand side of the plot with around half of the samples from Llanbadrig. Samples from the Outfall East and West sites and again half of the Llanbadrig sites were toward the left of this second grouping. This split suggests a greater dissimilarity between the Wylfa Head sites with the OE and OW sites but the magnitude of these differences in similarity was small (<5%).

To understand the sample groups on the right-hand side of the plot, the cluster diagram was redrawn with each site coded for ‘survey year’ (Figure 3.8). The result illustrated that most of the significant clusters contained samples from a single year only, although not all samples from any single year were clustered together. BG site composition showed no clustering by year suggesting that differences recorded in the communities had changed very little over the sampling programme.

A



B

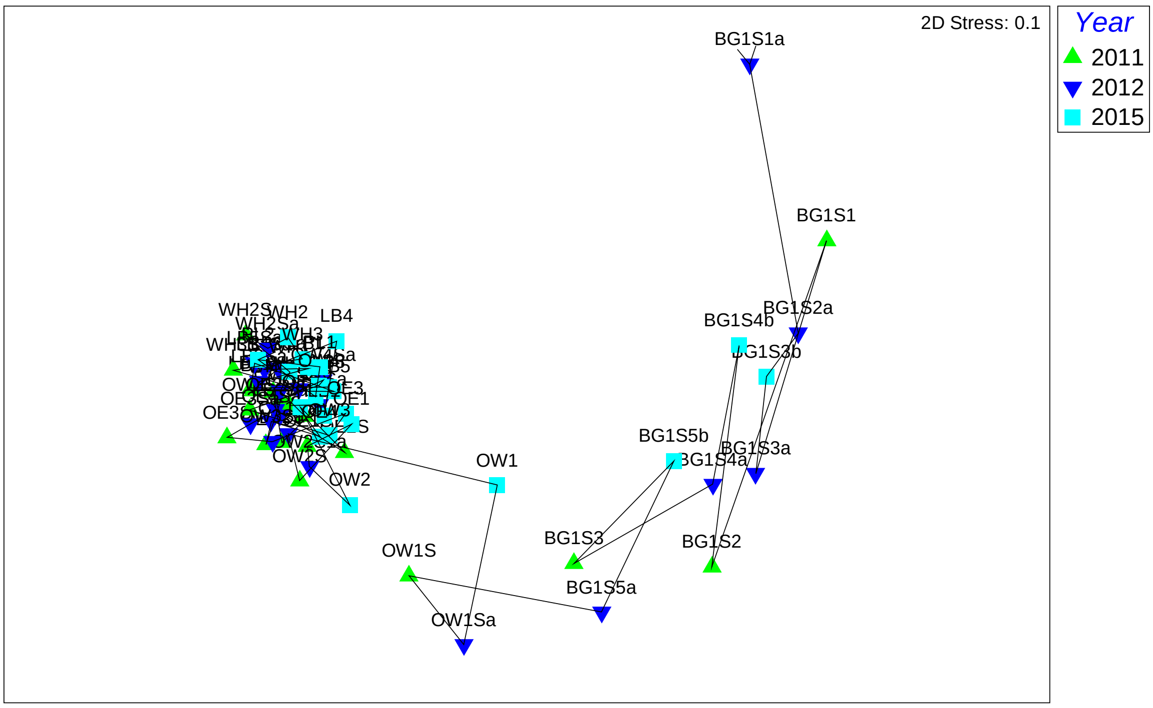
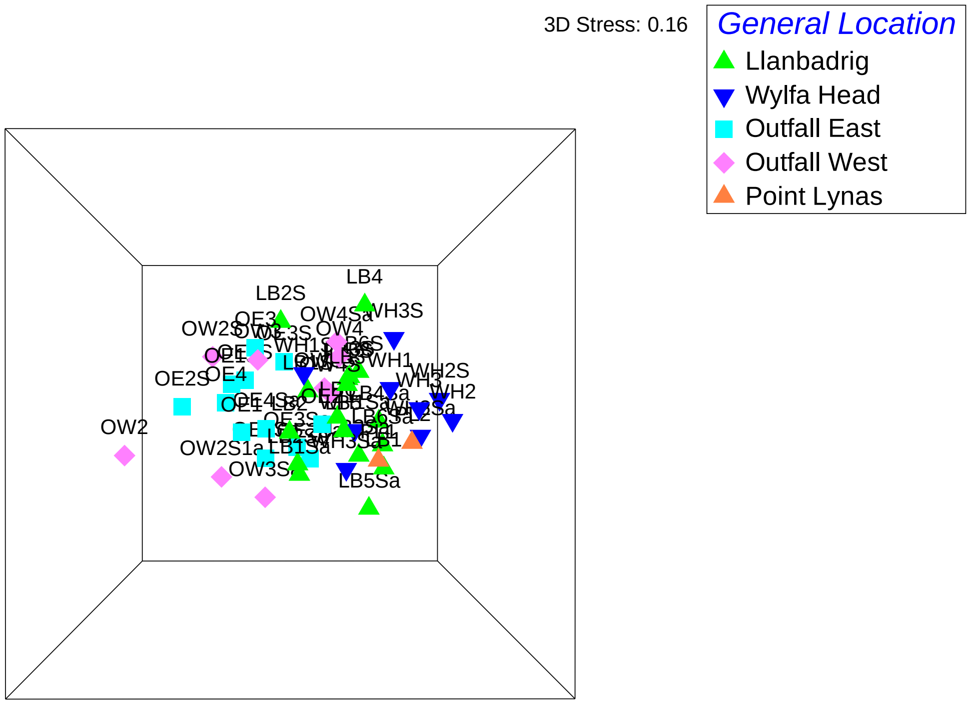


Figure 3.5: MDS plots of biota recorded along transects surveyed on north Anglesey at varying distances from the CW outfall at the Existing Power Station in 2011, 2012 and 2015. Data are displayed by (A) General Location and (B) survey year. Increasing distance from the CW outfall is shown by the black line, with the closest site depicted by arrow (BG1S1a in 2012). The suffixes 'a' and 'b' denote 2012 and 2015 samples respectively.

A



B

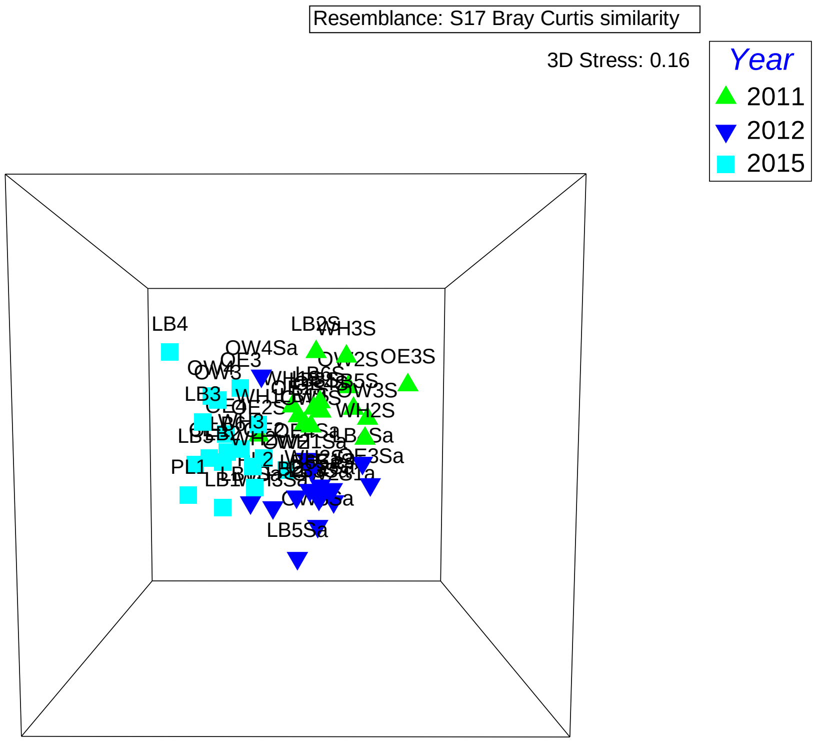


Figure 3.6: 3-dimensional MDS plots of biota recorded along transects surveyed on north Anglesey at varying distances from the CW outfall at the Existing Power Station in 2011, 2012 and 2015. Data are displayed by (A) General Location and (B) survey year. All BG sites and site OW1 have been excluded to allow greater illustration of any similarities within the main cluster.

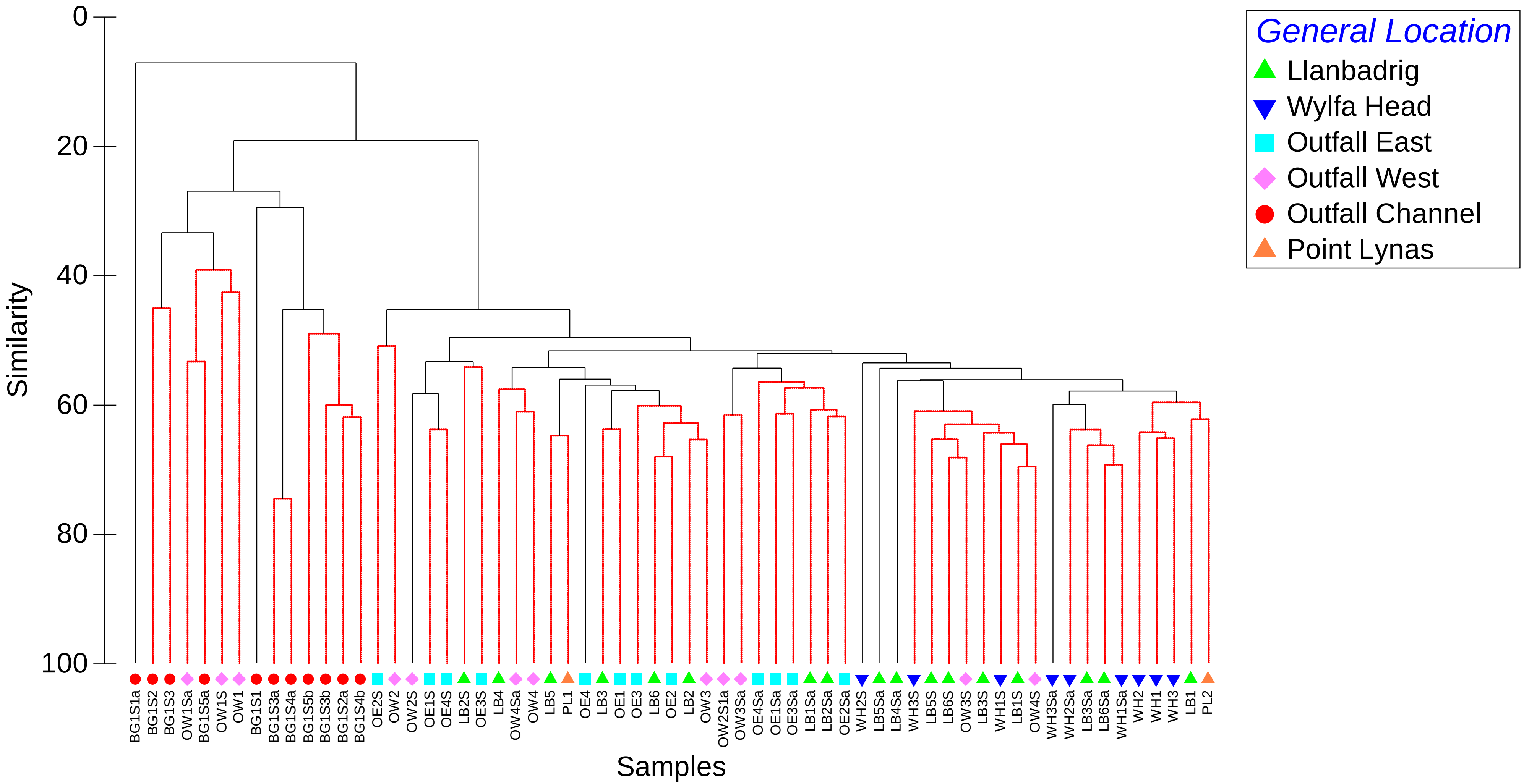


Figure 3.7: Cluster analysis and SIMPROF significance testing of shallow transect sites (joined red lines indicate significant clusters, $p<0.05$) surveyed in 2011, 2012 and 2015. The suffixes 'a' and 'b' denote 2012 and 2015 samples.

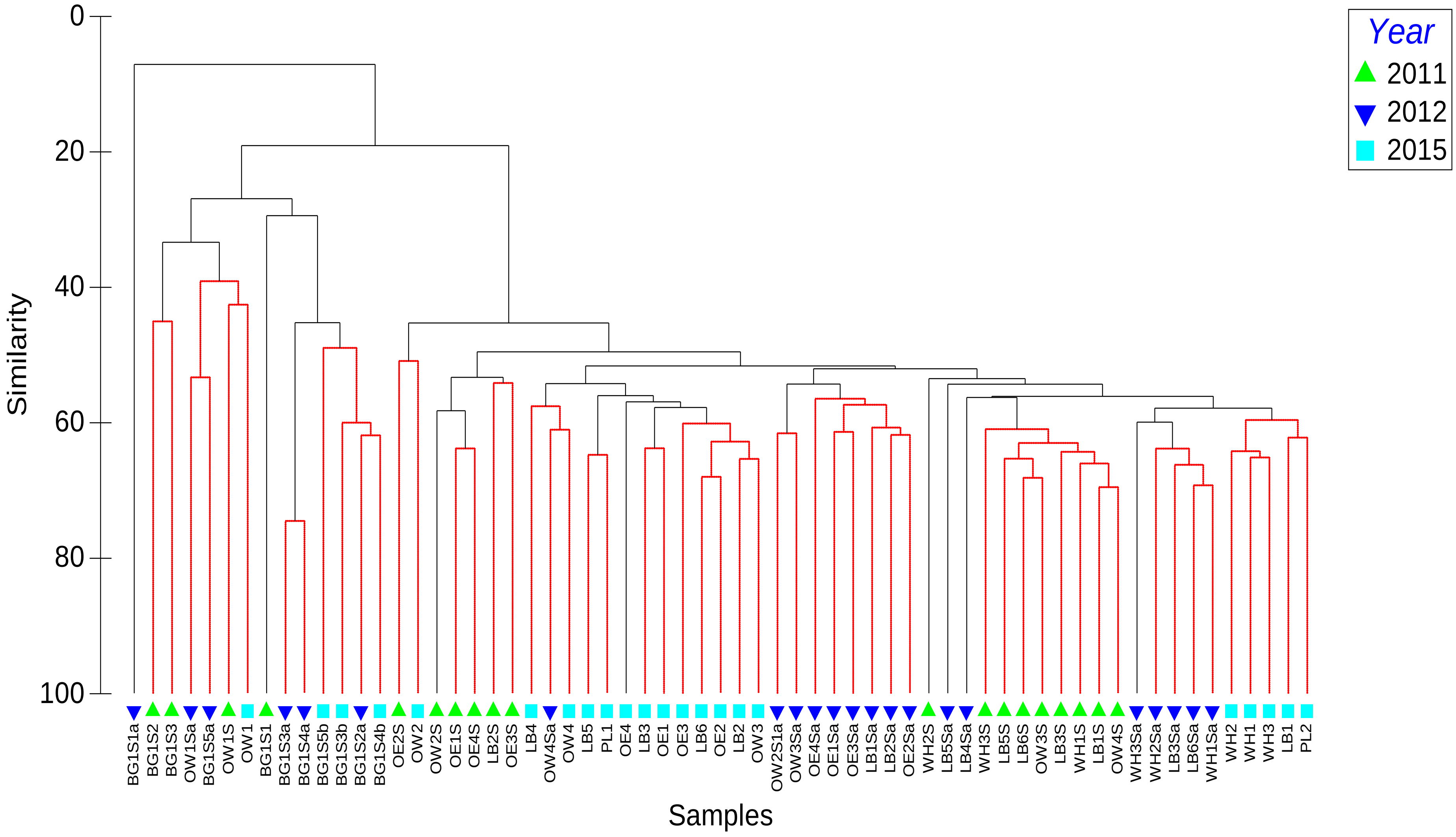


Figure 3.8: Cluster analysis and SIMPROF significance testing of shallow transect sites (joined red lines indicate significant clusters, p<0.05) surveyed in 2011, 2012 and 2015.

Three SIMPER tests were carried out to examine which taxa contributed most to any temporal differences between the sites within various locations. The tests were carried out on the General Locations once they had been divided, to allow sites closer to the outfall ('BG only' and 'OE and OW') to be examined in isolation from sites further afield ('WH and LB'), where ecological changes are less likely to have occurred following changes to the Existing Power Station's operating regime; given the apparent lack of detectable effect at these sites under full operation. Table 3.3 shows the average SIMPER dissimilarity scores between years for each of the sets of General Locations analysed. The average dissimilarity between years decreased consistently with increasing distance from the outfall, suggesting less variation in community survey records across time with increasing distance from the outfall. For the OE, OW, WH and LB sites, all but one taxa (Cirripedia spp. in 2011 vs 2015) gave contributions to dissimilarity of <2% suggesting differences between years were based on small differences in taxa composition rather than broad scale ecological changes in each area. For the Outfall Channel (BG) stations, the average dissimilarity scores were greater, with higher individual contributions (up to 7%) from taxa such as the anemone *Actinothoe sphyrodeta*, Cirripedia (barnacles), filamentous red algae and the red algae *Rhodymenia holmesii* and *Phyllophora truncata*; most contributions however, remained below 4%. The greatest differences at the BG stations between 2011 and 2012 were driven by greater abundances of *P. truncata*, Cirripedia, *A. sphyrodeta* and Ectocarpaceae in 2012. The smallest differences at the BG stations between 2012 and 2015 were again largely driven by greater abundances of the same taxa recorded in 2012 (with the exception of Cirripedia which were recorded at similar abundances in both years. This result suggests greater variation in community records from BG1 stations between years. The full SIMPER results are provided in the CD Appendix.

Table 3.3: Average dissimilarity scores from pairwise SIMPER analyses of survey sites in different General Locations at increasing distance from the Existing Power Station outfall from 2011, 2012 and 2015.

Year pairwise comparisons	Average dissimilarity
Outfall Channel (BG) sites (<75m from outfall)	
2011 and 2012	68.49
2011 and 2015	67.03
2012 and 2015	60.16
Outfall East and Outfall West sites (100 – 350m from outfall)	
2011 and 2012	52.26
2011 and 2015	52.58
2012 and 2015	52.99
Llanbadrig and Wylfa Head sites (465 – 3,300m from outfall)	
2011 and 2012	45.28
2011 and 2015	47.57
2012 and 2015	45.97

3.2 Intertidal quadrat surveys

In 2015, *Nucella lapillus* (dog whelk) was not recorded within the intertidal zone until 215m from the CW outfall as also recorded in 2010 (Figure 3.9(i)). In 1987 *N. lapillus* was not recorded until 255m from the outfall with an increase in abundance thereafter. In 2015, the mean numbers of *N. lapillus* were comparable to those from 1987 (Figure 3.9 (i)) but the pattern of increasing numbers with distance was not observed. Despite this, the intertidal data continued to suggest the species' absence closer to the outfall. However, *N. lapillus* populations can show patchy distributions (Bamber, 1989) and during the 2015 subtidal surveys, a small number of *N. lapillus* were recorded as 'rare' at sites BG1S3 and OW1 some 35m and 100m respectively, from the outfall. This was also the case at BG1S5 in 2012 (75m distant, 'rare') and BG1S2 and BG1S3 in 2011 (35m and 50m distant, 'occasional').

Patella spp. (limpets) were recorded at all sites in 2015 with the minimum mean number (4.4 per $0.25m^2$) at 40m and the maximum (15.6 per $0.25m^2$) at 215m from the outfall (Figure 3.9 (ii)). *Patella vulgata* and *Patella depressa* could not be easily distinguished in the field. To provide an indication of the relative proportions of these species, a sample of 47 limpets was taken from the subtidal zone, at approximately 60m from the outfall point. Of this sample, 31 limpets were *P. depressa* and 16 were *P. vulgata*; a ratio of 2:1. The 2015 data appeared to show a slight decline in the mean *Patella* spp. density at distances of 105m and closer to the outfall compared with samples taken beyond this point (Figure 3.9 (ii)). There was a weak, positive correlation (R^2=0.205) of increasing limpet density with increasing distance from the outfall.

In 2015, Cirripedia spp. (barnacles) were recorded at all sites with three discrete taxa identified from the quadrat photos: *Semibalanus balanoides*, *Chthamalus* spp. and *Austrominius modestus*. Mean percentage cover of Ciiripedia spp. increased rapidly with increasing distance from the discharge, from 1.8% at 10m to over 90% at 125m and beyond (Figure 3.9 (iii)). Similar patterns were observed in 1987 and 2010 with barnacles again recorded at all sites but decreasing rapidly toward the outfall.

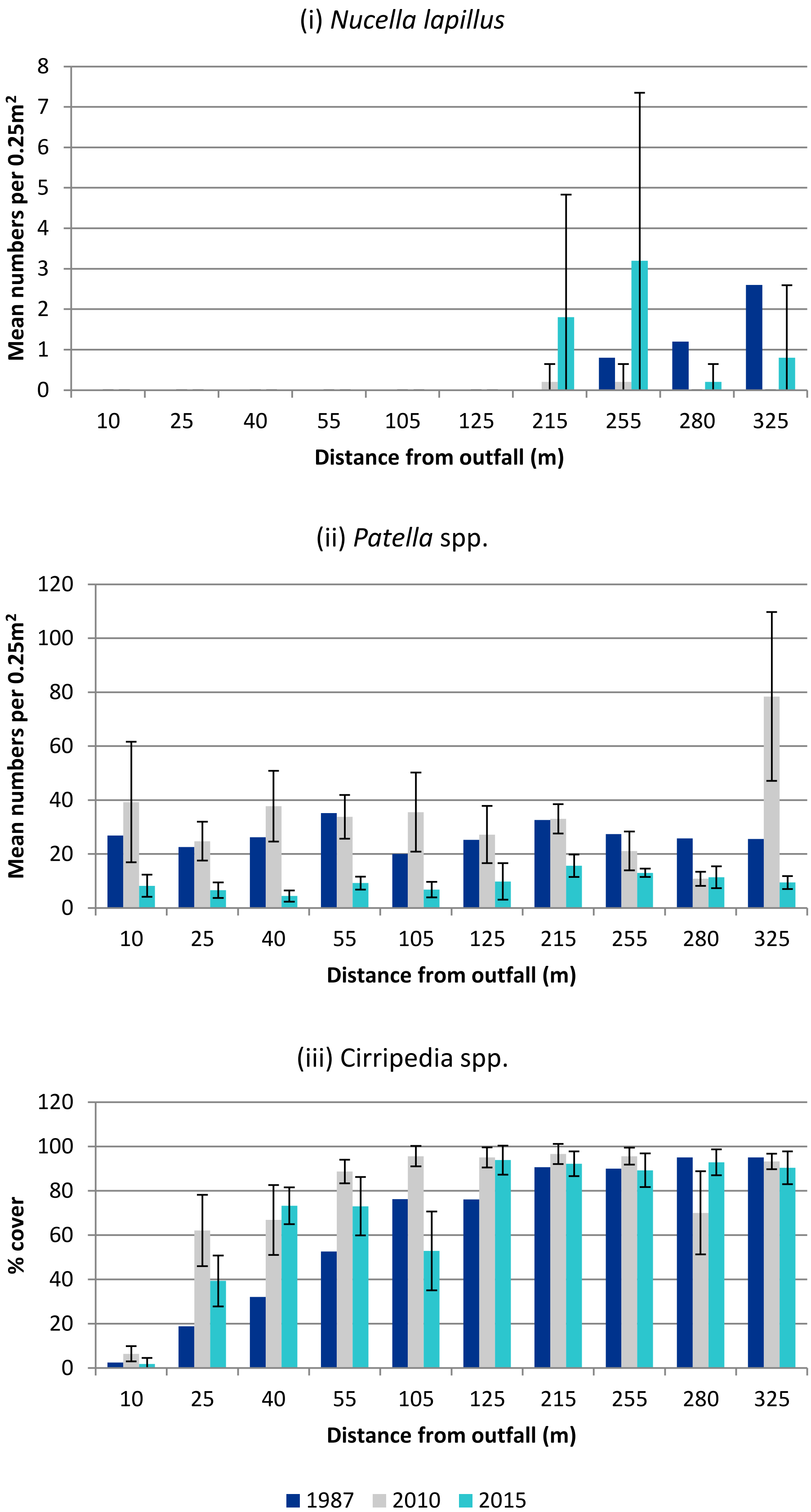


Figure 3.9: CW outfall transect taxa assessment data from 1987, 2010 and 2015 for the taxa *Nucella lapillus*, *Patella* spp. and Cirripedia spp.. Data shown are mean values +/- standard deviation. Standard deviation values are not available for the 1987 data.

4. Discussion

4.1 Subtidal dive surveys

Despite the comparatively limited temporal changes in the community composition, as identified by statistical analyses, this survey has shown that a number of the taxa found near to the outfall undergo shifts in abundance and/or presence, particularly the algal communities and some of the anemone species recorded from year to year. These data are useful for demonstrating that the majority of the detectable impacts on the benthos are limited to just a few hundred metres from the CW discharge, beyond this the thermal plume being readily dispersed by local currents.

The data suggest that despite the Existing Power Station operating with CW discharge reduced by approximately 50% since May 2012, the biota in the upper infralittoral, rocky reef communities continue to undergo rapid step-changes within 100m of the outfall point. Communities further afield showed little change in 2015 from those recorded when the station was fully operational in 2011 and 2012.This is evidenced within all data sets collected over the survey programme, from 2011, 2012 and 2015.

The discussion provided in the original survey report remains applicable to most of the results presented so far in this addendum and are not repeated here. Rather, the following sections discuss the analyses presented above and any specific differences identified from the 2015 surveys.

4.1.1 Statistical analysis

In 2015, the univariate measures showed notable decreases in taxa richness (S) and the Shannon Wiener diversity index H' ($\log_e$) within a distance of 100m of the outfall during all survey years (Table 3.2, Figure 3.4 and Jacobs, 2015a) as compared to values further afield, particularly at those sites greater than 450m from the outfall. Beyond 100m the H' ($\log_e$) and species richness values stabilised and although some degree of fluctuation was observed, the values for sites between 100 – 330m (OW1 – OE1) were generally comparable with those measured at the sheltered reference sites (i.e. LB1 – LB4). These observations reflected those recorded in previous years; with the subtle changes in community composition beyond 100m best examined using multivariate analyses.

The SIMPROF cluster analysis generated from the 2015 data showed similar results to that recorded in the 2011 and 2012 surveys, with the BG1 sites forming their own distinct cluster and OW1 and OW2 showing some separation from the other sites. Other than these sites no clear spatial patterns of community composition were observable, suggesting that statistically, beyond OW3 and OE1 inclusive, the sites from each General Location were indiscernible. Despite OE1 being the same distance from the CW outfall as OW1, it was clustered with sites much more distant from the outfall (e.g. OW4 and LB3). It is considered that this may be a result of the physical nature of the coastline, which initially deflects the main CW flow away from the OE sites toward the OW sites, before tidal back-eddies mix it with the receiving coastal waters which, during a flood tide, then push it back toward the OE sites at slightly cooler temperatures, albeit still above ambient (see Marston and Holroyd, 2012).

When the data were combined from all survey years the analyses showed the same spatial patterns as depicted in each individual year's analyses (Figure 3.7 and Figure 3.8). The sites BG1 and OW1 were quite separate from all the remaining sites, these remaining sites being further than 100m from the CW outfall. Some spatial variation existed, with the Wylfa Head sites being generally separated from the OE and OW sites. The small inter-annual differences apparent in Figure 3.5 and Figure 3.6 are not considered to represent large community changes, with each of the clusters being only a few percentage points apart (<8%) in terms of similarity. Despite regular team discussions on abundance estimates during the surveys, given the potentially subjective nature of SACFOR assessments and the potential for individual transects to move forwards or backwards several metres each year, these small, year-on-year differences could be expected. The main finding of the 2015 results appears to be that the spatial differences identified in 2011 and 2012, at varied distances from the outfall, have changed little, despite some minor but ecologically insignificant variation in community records year on year.

4.1.2 Taxa distributions

This section addresses each of the major taxa groups in turn and provides a comparison with data from 2011 and 2012. References are made to abundances based on the SACFOR scale (Appendix B) in brackets where appropriate.

4.1.2.1 Algae

The overall patterns of algal distribution at the survey sites in 2015 had changed little since the surveys in 2011 and 2012. As distance from the CW outfall decreased the general pattern of algal composition and abundance changed noticeably in all years with a sharp drop in red algae abundance and richness evident from OW1S. Whilst most taxa tended to reduce in abundance or presence with proximity to the outfall (e.g. *Plocamium* spp., *Cryptopleura ramosa, Rhodophyllis divaricata*, *Furcellaria lumbricalis* and *Heterosiphonia plumosa*), some red algae showed increased abundances, namely *Rhodymenia holmesii*, *Phyllophora pseudoceranoides* and *Callophyllis laciniata*. However, even these latter species had tolerance limits with BG1S3 supporting very few red algal taxa (n=3). The main patterns in red algal taxa abundance and presence/absence described in the previous report (Jacobs, 2015a) remained the same following three years of reduced operation and are not repeated in detail here.

The non-native red alga, *Asparagopsis armata* was recorded close to the outfall (OW3, 'rare') in 2015 but at no greater or lesser density than that recorded previously (BG1S3 and OW1, 'rare' to 'frequent'). It is worthy of repetition here that this species has been recorded in other diving surveys at greater distances from the CW outfall and at greater densities, for example in Porth-y-pistyll Bay it was recorded as 'occasional' to 'abundant' in 2011 and 2012, and was also recorded from Point Lynas in 2015. Likewise, *Heterosiphonia japonica* was recorded from sites OE1 and OW1 as 'rare' in 2015 and had previously been recorded from sites OE2 and LB6 ('rare') in 2011 and also in Porth-y-pistyll Bay in 2011 and 2012 ('rare').

The greater abundance of coralline encrusting algae recorded at the Outfall Channel sites in all years might be due to both a lack of competition from other species and from a lack of cover from filamentous and foliose species making it more obvious to surveyors.

The most noticeable change within the brown algae community, other than a fall in overall richness at the BG stations, was a lack of kelp (*Laminaria hyperborea*) in all years at OW1 and BG1. As in 2011 and 2012, at the next western site (OW2) kelp was present at densities consistent with other sites in the region. Despite OE1 being the same distance from the outfall as OW1, the physical nature of the shoreline in this area provides greater shelter from direct interaction with the outfall water, resulting in lower exposure to thermal stress; therefore, kelp was present at this site, as in previous years.

Increased abundances of *Halopteris scoparia* (previously *Stypocaulon scoparium*) and *Halopteris filicina* occurred toward the outfall. Of these two species, *H. scoparia* appeared most tolerant of the elevated temperatures, remaining present to within at least 75m of the outfall point in 2015. Again, this was the same pattern of distribution of these species as recorded in 2012. The lack of records for *H. scoparia* in 2011 might simply be due to taxonomic uncertainty at the time of survey as the congeneric *H. filicina* which was recorded in 2011 is extremely similar morphologically making *in situ* identification difficult.

As per 2011 and 2012, the most commonly recorded green alga during the surveys (*Cladophora* spp.) was most abundant approximately 70m from the CW outfall where it was noted as 'frequent' in 2011 and 2012 and 'occasional' in 2015. Closer than this, in 2012, at BG1S3 (approximately 30 m) only the taxa *Derbesia marina* ('frequent') and small green filamentous algae ('occasional') were recorded from the phyla Chlorophyta and these were not evident any closer to the CW outfall (i.e. at BG1S1 and S2). In 2015, *D. marina* was only recorded at OW1.

As in previous years, the non-native green alga, *Codium fragile* was recorded at BG1S5 in 2015; however, unlike 2011 and 2012 it was not recorded at OW1.

4.1.2.2 Sponges

Sponges were notably absent from BG1 in 2011 and 2012, and from OW1 in 2012 and 2015. Taxa such as *Leucosolenia* sp. and *Sycon ciliatum* were present at OW2 with a gradual increase in sponge diversity toward OW4. The number of sponge taxa recorded at the OE sites showed a steep, variable increase as increasing distance from the outfall but was frequently higher than at the OW sites, with up to 13 taxa recorded at OE2. Only three sponge taxa were recorded at OE4 (*S. ciliatum*, *Pachymatisma johnstonia* and *Stelligera* sp.) which corresponded with an equally low number recorded in 2011.

Further from the CW outfall area, the species richness and abundance of sponges increased. The highest sponge diversity was found at survey sites on Wylfa Head (WH1 – 3 with 19, 16 and 16 taxa respectively) with the number of sponge taxa at Llanbadrig and Point Lynas ranging between 6 – 16 and 11 – 17 respectively. There appeared to be no clear relationship between sponge taxa records and distance from the outfall at these more distant sites (WH, LB and PL). The sponge taxa at Point Lynas corresponded well with those from Wylfa Head and Llanbadrig with some increased abundances of *S. ciliatum* and *Leucosolenia* spp. (both ‘frequent’ to ‘common’) and *Polymastia boletiformis* (‘occasional’ to ‘frequent’).

4.1.2.3 Cnidarians

As in previous years, there were no records of hydroids from BG1 in 2015. The first record was *Coryne muscoides* at OW1. The number of hydroid taxa recorded at the OW sites increased very slowly, with *Tubularia indivisa*, *Eudendrium* spp., *Nemertesia antennina*, *Plumularia setacea* and *Obelia* spp. appearing at sites OW3 and OW4 as well as *Alcyonium digitatum*; all were recorded as ‘rare’ or ‘occasional’. The number of hydroid taxa at the OE sites also remained low with a similar species complement before increasing sharply further afield from the outfall, at the WH, LB and PL sites.

Dead men’s fingers (*A. digitatum*) and the hydroid *N. antennina* were some of the most commonly recorded Cnidaria in 2011 and 2012. In 2015 these taxa were present in varying abundances at most of the sites although both were absent from the BG sites, OW1, OW2, OE1 and OE4. *Obelia* spp. was recorded wherever kelp was present, with the exception of OE4 and OW2.

The only anemone recorded at BG1 in 2015 was *Actinothoe sphyrodeta*. This species was also found in the outfall channel in 2011 and 2012, although in previous years other anemones were recorded at BG1 including *Cereus pedunculatus*, *Anemonia viridis* and *Actinia equina*. In 2015, *C. pedunculatus*, *A. equina*, *Urticina felina* and *Sagartia elegans* were all recorded at either OW1 or OW2. *A. viridis* was absent from all 2015 survey records, whereas previously it was throughout BG1 and the OW sites (greatest abundance at OW1) in 2011 and 2012 with one record at OE2 in 2011 but not further afield.

The beadlet anemone (*A*. *equina*), generally considered an intertidal species, was present at OW1, LB2, WH1 and WH3 in 2015. Previously this species had only been recorded from BG1 and the OW1 sites. Records from sites further afield (i.e. LB2, WH1 and WH3) were made in the shallower, kelp park habitats whereas the record from OW1 in 2012 was from the upper circalittoral, below the kelp park.

4.1.2.4 Crustaceans

The crustaceans recorded consisted mainly of barnacle, prawn and crab taxa. As in previous years there were very few clear patterns in the distribution of these taxa, most likely owing to their cryptic nature. Velvet swimming crabs (*Necora puber*) and brown crabs (*Cancer pagurus*) were recorded from half the sites and although there were no clear patterns of distribution, both species were absent from BG1 and sites OW1 and 2.

The taxon Cirripedia spp. (barnacles) was ubiquitous in 2015 and was at consistently high abundances at BG1, OW1 and OE1, although abundances were also high at LB3 and LB4. The assessment of barnacle abundance close to the outfall has varied in previous surveys (Jacobs, 2015a) and records from 2015 were comparable to those in 2012.

4.1.2.5 Molluscs

There were no clear patterns in the distribution of molluscs across the transects, although the number of taxa was notably lower at the sites closest to the CW outfall in each year (BG1, OW1, OW2). The apparent increase in abundance of limpets at BG1 might simply be owing to the lack of algal cover making them more visible to surveyors.

In 2015 the most commonly recorded molluscs were the sea slugs *Janolus cristatus* and *Tritonia lineata*, recorded at 16 and 10 sites respectively. The most frequently recorded molluscs in 2011 were the grey topshell (*Gibbula cineraria*) and the sea slugs *Aplysia punctata*, *T. lineata* and *Limacia clavigera*. The most commonly recorded molluscs in 2012 were the topshell *G. cineraria* (at 13 of the shallow sites) and the nudibranch *J. cristatus* (15 sites). By contrast *G. cineraria* were recorded at seven sites in 2015.

4.1.2.6 Bryozoans

Bryozoans were commonly recorded on the headland sites (WH, LB and PL). There was a slight decrease in the number of taxa at LB1 – 3 compared with the other LB and WH sites which was most likely owing to the more sheltered nature of the sites; these lower taxa counts were comparable to those recorded from the OE and OW sites. Bryozoans were absent from BG1 within the main outfall channel, as was found in 2011 and 2012. The most commonly recorded taxa were crisiids (17 sites), *Electra pilosa* (18 sites) and 'bryozoan crusts indet.' (18 sites).

In 2011, crisiids were absent from BG1 and the shallow OW1, OW3, OE1 and OE3 sites, and notably lower in abundance at OE2 and OW2 ('rare') compared with sites further afield (WH, LB and PL). In 2012 crisiids were absent from BG1S3 – BG1S5 and OW1. In 2015 crisiids were recorded as 'rare' at all OW sites but remained absent from BG1. Crisiids were also not recorded at LB3 and LB4 though they were recorded as 'rare' to 'abundant' at the other LB sites in 2015.

E. pilosa was recorded from all sites, with the exception of BG1 and OW2 in 2015. In previous surveys it had been present at OW2 but absent from OW1.During 2015 bryozoan crusts were absent from BG1 and LB3 but recorded as 'present' to 'occasional' at all other sites. The distribution pattern of both these taxa was similar to those recorded in 2011 and 2012.

4.1.2.7 Echinoderms

There was a general decline in the number of echinoderm taxa recorded and their relative abundances as the outfall was approached. The most widely recorded species in all years was *Asterias rubens* (15 sites in 2015) which was found at BG1S5, and at a similar distance from the outfall, at BG1S3 in 2011 (see Appendix D for comparative distance between years). Notably higher abundances of *A. rubens* were recorded at the OW sites as compared with the OE sites, although no clear gradients of changes in abundance or species distribution were evident. *Henricia* spp. was also frequently recorded across the survey area (at 14 sites in 2015).

The feather star *Antedon bifida* was recorded as 'rare' from BG1S3 in 2015. Previously it had not been recorded closer to the outfall than at OW1 and OE1 in 2012.

4.1.2.8 Tunicates

In 2015, no tunicates were recorded from BG1. This was also the case in 2012, although in 2011 both *Morchellium argus* and *Ascidiella scabra* were recorded in low abundances ('rare') at BG1S3 (the equivalent distance to sites BG4 and 5 in 2012 and 2015). The closest records of tunicates to the CW outfall in 2015 were *Clavelina lepadiformis* ('rare' to 'occasional') at OW1 – 2 and *M. argus* and *Aplidium punctum* at OW2. *C. lepadiformis* and *A. punctum* were the most frequently recorded tunicates across the survey area, being recorded from 19 and 18 sites respectively.

No non-native tunicates were recorded in 2015. The only previous non-native record was of *Corella eumyota* (rare) at OE2 in 2012.

4.1.2.9 Fish

In total, 11 fish taxa were recorded during 2015, around half that recorded in 2011 and 2012. This is considered more a result of decreased underwater visibility as compared with previous years' surveys, than any other variable. In general, fish taxa were recorded sporadically and in low abundances ('rare' to 'occasional'). The greatest and most obvious effect of the CW outfall was, as in previous surveys, were the notably high abundance of bass (*Dicentrarchus labrax*) which was recorded as 'common' at BG1S3.

4.1.3 Biota assemblage

In terms of the key contributing taxa to community assemblages across the survey sites as a whole, there were notable absences at the BG sites of epifauna from the groups Porifera, Bryozoa and Tunicata. The absence of these taxa resulted in the percentage contributions of others, particularly Rhodophyta, to increase at these proximal outfall sites, albeit by very variable amounts depending on the distance from the discharge point.

Of the Cnidaria, the anemone *Anemonia viridis* was not recorded in 2015. This was in contrast to 2011 and 2012 where it was recorded as 'frequent' to 'rare' at several BG, OW and OE sites but was not recorded elsewhere. *A. viridis* is a southern species, and is considered susceptible to low water temperatures (see Crisp, 1964). Given the changes to the operating regime of the Existing Power Station, to using just a single reactor since spring 2012, when an outage has occurred the heat output of the CW outfall has ceased for periods of several weeks or months. The outages have taken place over a number of seasons, including a six month period in 2014 from early January to the end of June (see Section 1.4). It is possible that exposure to colder water temperatures during these outages resulted in some die-back of *A. viridis* but given the nature and timing of the survey methodology, it is not possible to determine cause-and-effect with absolute certainty, particularly given that north Anglesey is well within the anemone's known UK, north-south geographic range.

The same may also be true for the non-native green alga *Codium fragile* as described above for *A. viridis*. *C. fragile* is better adapted to warmer waters with its spread limited by cooler temperatures (JNCC, 2015) and again, a prolonged period with little or no CW discharge above ambient temperatures might have resulted in some die-back of this species. Since the present surveys commenced in 2011, *C. fragile* has not been recorded at any of the other survey sites further from the CW outfall.

In 2015, the feather star *Antedon bifida* and the common prawn *Palaemon serratus* were recorded as 'rare' at BG1S3, the closest point surveyed to the CW outfall (within 35m); neither being previously recorded closer than OW3 and OW2, respectively. Both are mobile species and might have been present in 2015, either due to reduced temperatures on the bed or the reduced flow and turbulence making it possible for them to physically migrate toward this site. Despite these new records, only several individuals of each species were recorded and did not constitute any major shift in the assemblage composition. .

Tunicate records at BG1 and OW1 were few in 2015 and 2012, as compared with 2011. This lower number of records in 2012 and 2015 is not easily explained by the changes to station operation and could be due to random fluctuations in species presence/absence or the cryptic nature of some species meaning they may have gone unrecorded. The number of fish species recorded in 2015 was comparable with previous years.

4.1.4 Thermal effects and community tolerances

Despite the likely and prolonged periods (several months in 2014) without thermal input to the outfall bay, the community patterns recorded in June 2015 corresponded well with those from 2011 and 2012. This suggests that when the CW outfall was operational, between spring 2012 and June 2015, its effects on the surrounding communities remained acute and of a very similar magnitude to those recorded under full operational conditions. The nature of the thermal exposure of the communities within the outfall bay (BG, OW and OE sites), and its likely effects are discussed in the main report (Jacobs, 2015a) but are considered to be mainly due to the intolerance of the resident species to constant fluctuations in temperature (shifting interface) throughout a tidal cycle, rather than the absolute temperatures experienced.

In the main report (Jacobs, 2015a), it was mentioned that these rapid temperature fluctuations in the shallow subtidal habitats within the CW outfall bay probably result in considerable physiological stress to subtidal species. In 2011, 83% of the 23 invertebrate taxa present in the CW outfall channel (BG1S3 – 5) were recognised as occurring in intertidal habitats under natural conditions (though they may also be found in subtidal habitats). Similarly this percentage was 85% in 2012 and 89% in 2015. In contrast, at the three sites on Wylfa Head, only 35% of the invertebrate taxa recorded in 2011 were recognised as occurring in intertidal habitats, indicating this was a more suitable and stable environment for subtidal species. A similar pattern to that seen with the fauna was observed for the algae found close to the CW outfall; 75% of the floral taxa identified at the BG1S3 – BG1S5 in 2011 are recognised as occurring (at least some of the time) in intertidal habitats. In 2015 this was 85%, again suggesting a greater inherent tolerance in the taxa present to the prevailing conditions. Algae might also be more sensitive to thermal stress, with some species possibly having thresholds <25°C (UNEP, 1981). Therefore the exclusion of algal species close to the outfall might be due to both elevated temperatures and/or large temperature fluctuations.

In the immediate, narrow confines of the main CW outfall channel (<40m from the outfall) it is possible that along with the elevated and fluctuating temperature regime, the mechanical stress of the turbulent water flow plays some role in diminishing the local flora and fauna. However, without prolonged CW discharge over several years at ambient temperature, the contribution of this factor alone (as with any of the potential stressors) is impossible to quantify separately. Mechanical stress is unlikely to be an issue at any sites beyond BG1, such as OW and OE sites which have flow rates notably lower than those experienced at the BG sites and, further afield, at the WH and some LB sites. For this reason it is considered that the communities at OW and OE are largely beyond any influence of water turbulence produced by the CW outfall.

Despite the volume of water discharged being approximately halved since May 2012 the temperature rise of the discharged water has remained the same. It is thought that the narrow channel may be at or near its carrying capacity of warm water, before mixing can occur with the receiving coastal waters. Without detailed model outputs to demonstrate whether or not this is actually the case, the latter remains only a hypothesis based on informed field observations of the ecological communities and continued turbulent nature of the CW outfall bay. However, should this be the case it would explain why temporal changes in the community were very limited between 2015 and previous survey years.

A further discussion of the community changes associated with the CW outfall and comparison with other similar studies is given in the main report (Jacobs, 2015a).

4.2 Intertidal quadrat surveys

The records of *Nucella lapillus* at much closer distances to the outfall in all subtidal survey years than previously recorded in the intertidal surveys, could suggest that the species is more limited by suitable physical habitat in the area, rather than the conditions of elevated and fluctuating water temperature. Furthermore, existing at low densities and in hard-to-reach crevices at low tide along the steep outfall shoreline, the species might simply have a reduced likelihood of being present in the survey quadrats. There could of course still be changes in density of *N. lapillus* with distance from the outfall as reported by Bamber (1989) but the very low numbers recorded during the present study coupled with the records from the subtidal surveys suggest a revised methodology might be appropriate.

In the previous studies, Bamber (1989) and Jacobs (2015b) the only limpet recorded from the quadrat surveys was *Patella vulgata.* Due to the inherent difficuties with speciating between patellids (requires physcial removal from substratum and then careful examination of the mantle) it is not thought that *in situ* examination of these fauna is practical and may explain why no records of *P. depressa* exist for the historic intertdial surveys. However, to cover the uncertainty the taxa entry *Patella* spp. was used for all years.

A clear decline in limpet abundances was shown in 2015, as compared with the 1987 and 2010 surveys. The raw data from the 1987 study were not available but the mean values were largely comparable with those from 2010, with the exception of the site at 325m distant from the outfall. A two-sample *t*-test confirmed that the mean number of *Patella* spp. recorded per quadrat was significantly less in 2015 (9.4 per 0.25m^2) compared with 2010 (35.0 per 0.25m^2) (T=8.13, df=98, p<0.001), and by reasonable assumption based on Figure 3.9 (ii), also significantly lower than in 1987.

Whether or not the observed weak correlation of limpet density with distance is a true reflection of outfall impacts is questionable given that the same pattern of increase was not apparent in 1987 or 2010. In these earlier years, the Existing Power Station was fully operational, limpet abundances were greater and any trend could therefore be expected to be stronger than the observations in the present study. The result may simply be a result of patchy distribution of the species, random year-on-year variation in abundance and/or differences in the exact points sampled on the shore by each survey team.

The distance at which barnacles reached a consistent cover of >90% varied between survey years from 105m and 215m, though the changes in these distances did not show an increasing or decreasing relationship with time or station operation. Patterns of individual taxa abundance were not investigated as this was not done in previous years; furthermore, identification of all individuals in each image was not possible due to shadows and/or the angle of the rocky shore.

As discussed by Bamber (1989), the intertidal biota in the immediate vicinity of the discharge was impoverished and remained so despite the prolonged period of reduced operation since spring 2012. Bamber considered this impoverishment to be related to thermal stress rather than the influence of scour or the effects of antifouling agents in the cooling water and discussed similar effects recorded at other power stations such as Hinkley Point, Somerset (Bamber and Coughlan, 1987). Bamber (1989) made the point that barnacles are often found in habitats with increased tidal flow, making scour an unlikely reason for the reduction in percentage cover close to the outfall. Furthermore, given that barnacles are often found fouling power station outfall culverts, the low-levels of residual anti-fouling treatments are unlikely to inhibit their growth (Bamber, 1989). Consequently, it is considered that the patterns of Cirripedia spp. abundance recorded since 1987 were largely the result of temperature effects from the discharge. Based on all data from 1987, 2010 and 2015, the spatial extent of any such effects might vary slightly between any given years but are generally limited to within 200m of the outfall. These results correspond with those of the subtidal habitat transects described above in section 4.1.

5. Conclusions

The empirical evidence provided by this study continued to show differences between both the shallow subtidal and intertidal communities at the proximal CW outfall sites and those communities surveyed beyond the CW outfall channel.

At distances <100m from the CW outfall the ecological impacts on the communities seen throughout these surveys were manifested as:

- changes in dominance of key taxa e.g. kelp;
- greater presence/dominance of taxa associated with the intertidal;
- general decreases in taxa richness and diversity; and
- changes in community composition.

Beyond a distance of 100m subtidal benthic communities showed similar patterns to those described in previous years, with sites to the west showing a gradual return to 'reference' status with distance whilst the OE sites showed more random variation.

After some three years of the Existing Power Station operating at a reduced load, the surveys of the shallow, subtidal, rocky reef communities showed:

- A clear, acute spatial impact within 100m of the CW outfall. The impact was on the same spatial scale as that observed under full operational conditions and reported in Jacobs (2015a).
- Year-on-year community variation greater at sites closer to the CW outfall (BG, OW and OE), as indicated by the greater dissimilarities between years at these sites, compared to those observed for sites further afield (LB and WH).
- A more noticeable impact on those sites immediately to the west of the CW outfall as compared with sites equidistant to the east. Thermal imaging data obtained during full-load operation showed that the plume has a greater residency time towards the west of the channel than the east, and the results of the 2015 survey suggest this remains the case even with a reduced station operating regime.
- The CW outfall did not support an unusual abundance of non-native species. *Asparagopsis armata* and *Heterosiphonia japonica* continued to be present at other sites, further afield, in comparable abundances.

The intertidal outfall survey showed:

- Biota in the immediate vicinity of the discharge were impoverished and had remained so despite the prolonged period of reduced station operation since spring 2012.
- *Nucella lapillus* (dog whelk) was not recorded within 215m of the outfall. Its presence recorded during subtidal surveys since 2011 at distances of 35m and 50m from the outfall suggests its absence from the intertidal data might be an artefact of the inaccessible nature of the shoreline and/or lack of habitable space, rather than exclusion owing to water temperatures.
- *Patella* spp. (limpets) did not appear to show any consistent spatial population trends in relation to the CW outfall.
- Cirripedia spp. (barnacles) showed a decline in percentage cover within 125m of the outfall in 2015, though the distance at which this decline began varied year-on-year.

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Appendix A. Field logs and site positions

Table A1: Survey dive team 2015

Field team	Role
Matt Doggett (MD)	Diver/Surveyor/Supervisor
Harry Goudge (HG)	Diver/Surveyor/Supervisor
Kate Northern (KN)	Diver/Surveyor/Supervisor
Colin Trigg (CT)	Diver/Surveyor/Supervisor
Emma Collins (EC)	Diver/Surveyor
Jack Egerton (JE)	Technical Assistant

Table A2: Survey times and conditions in 2015

20th June 2015

Weather:	Wind S-SW F2-3, overcast, light drizzle
Sea:	Calm
Tide:	HW Cemaes, 5.86m, 1304h UTC
Summary	
1129h	MD and EC dive OW1
1152h	CT and KN dive OW2
1517h	CT and KN dive OE4
1526h	MD and EC dive OE3

21st June 2015

Weather:	Wind F4-5 W, mostly cloudy
Sea:	Moderate
Tide:	HW Cemaes, 5.62m, 1345h UTC
Summary	Down weather day – poor sea conditions, sample QC sessions

22nd June 2015

Weather:	Wind F3-4 W-NW, partly cloudy
Sea:	Moderate
Tide:	HW Cemaes, 5.38m, 1430h UTC
Summary	Down weather day – poor sea conditions, sample QC sessions

23rd June 2015

Weather:	Wind F2-3, S-SSW, scattered clouds
Sea:	Calm
Tide:	HW Cemaes, 5.16m, 1519h UTC
Summary	
0828h	CT and EC dive WH2
0842h	HG and KN dive WH1
1228h	CT and EC dive LB1
1359h	HG and KN dive LB4

24th June 2015

Weather:	Wind F3-4, S, overcast
Sea:	Calm
Tide:	HW Cemaes, 4.99m, 1611h UTC
Summary	
0856h	MD and EC dive OW3
0914h	HG and KN dive OW4
1248h	MD and EC dive LB2
1303h	HG and KN dive LB3

25th June 2015

Weather: Wind F3-4, S, foggy start, clearing to overcast
Sea: Calm
Tide: HW Cemaes, 4.94m, 1712h UTC

Summary

1200h KN and EC dive OE1
1214h MD and CT dive OE2
1604h KN and EC dive WH3
1733h MD and CT dive BG1

26th June 2015

Weather: Wind F3-4, SSE-SW, overcast with showers
Sea: Calm
Tide: HW Cemaes, 5.01m, 1815h UTC

Summary

0939h HG and MD dive LB5
0934h EC and CT dive LB6
1326h HG and MD dive PL1
1337h EC and CT dive PL2

Table A3: Survey site positions, dates and surveyors in 2015. Positions given are the approximate centre point of each transect.

Site Ref.	Site Location	Latitude	Longitude	Date	Surveyors
BG1S3	Outfall Channel	N 53° 25.145	W 04° 28.862	25/06/2015	MD, CT
BG1S4	Outfall Channel	N 53° 25.149	W 04° 28.868	25/06/2015	MD, CT
BG1S5	Outfall Channel	N 53° 25.152	W 04° 28.882	25/06/2015	MD, CT
OW1	Outfall West	N 53° 25.155	W 04° 28.907	20/06/2015	MD, EC
OW2	Outfall West	N 53° 25.186	W 04° 28.950	20/06/2015	CT, KN
OW3	Outfall West	N 53° 25.197	W 04° 29.014	24/06/2015	MD, EC
OW4	Outfall West	N 53° 25.202	W 04° 29.042	24/06/2015	HG, KN
OE1	Outfall East	N 53° 25.198	W 04° 28.876	25/06/2015	KN, EC
OE2	Outfall East	N 53° 25.214	W 04° 28.850	25/06/2015	MD, CT
OE3	Outfall East	N 53° 25.230	W 04° 28.810	20/06/2015	MD, EC
OE4	Outfall East	N 53° 25.284	W 04° 28.779	20/06/2015	CT, KN
WH1	Wylfa Head	N 53° 25.337	W 04° 28.734	23/06/2015	HG, KN
WH2	Wylfa Head	N 53° 25.351	W 04° 25.675	23/06/2015	CT, EC
WH3	Wylfa Head	N 53° 25.346	W 04° 28.589	25/06/2015	KN, EC
LB1	Llanbadrig	N 53° 25.477	W 04° 26.588	23/06/2015	CT,EC
LB2	Llanbadrig	N 53° 25.510	W 04° 26.527	24/06/2015	MD, EC
LB3	Llanbadrig	N 53° 25.525	W 04° 26.548	24/06/2015	HG, KN
LB4	Llanbadrig	N 53° 25.537	W 04° 26.580	23/06/2015	HG, KN
LB5	Llanbadrig	N 53° 25.607	W 04° 26.423	26/06/2015	MD, HG
LB6	Llanbadrig	N 53° 25.616	W 04° 26.388	26/06/2015	CT,EC
PL1	Point Lynas	N 53° 24.896	W 04° 17.487	26/06/2015	MD, HG
PL2	Point Lynas	N 53° 24.939	W 04° 17.462	26/06/2015	CT,EC

Appendix B. MNCR SACFOR abundance scales

Table B1: MNCR SACFOR abundance scale (JNCC, 2006)
S=Superabundant, A=Abundant, C=Common, F=Frequent, O=Occasional, R=Rare.

When species (such as those associated with algae, hydroid and bryozoan turf or on rocks and shells) are incidentally collected (i.e. collected with other species that were superficially collected for identification) or when no meaningful abundance can be assigned to them, they were noted as present (P).

Growth Form	Size of Individuals/Colonies		Size of Individuals/Colonies					
Percentage cover (%)	Crust/ meadow	Massive/ Turf	<1 cm	1-3 cm	3-15 cm	>15 cm	Density	
>80%	S		S				>1/0.001m^2 (1x1cm)	>10,000/m^2
40-79%	A	S	A	S			1-9/0.001m^2	1000-9999/m^2
20-39%	C	A	C	A	S		1-9/0.01m^2 (10 x 10cm)	100-999/m^2
10-19%	F	C	F	C	A	S	1-9/0.1m^2	10-99/m^2
5-9%	O	F	O	F	C	A	1-9/1m^2	
1-5% or density	R	O	R	O	F	C	1-9/10m^2 (3.16 x 3.16m)	
<1% or density		R		R	O	F	1-9/100m^2 (10 x 10m)	
					R	O	1-9/1000m^2 (31.6 x 31.6m)	
						R	<1/1000m^2	

Table B2: Examples of groups or species for each SACFOR category (Moore, 2004).

	Crusts	Massive	<1 cm	1-3 cm	3-15 cm	>15 cm
PORIFERA	Crusts *Halichondria*	Massive spp. *Pachymatisma*		Small solitary *Grantia*	Large solitary *Stelligera*	
HYDROZOA		Turf species *Tubularia* *Abietinaria*		Small clumps *Sarsia* *Aglaophenia*	Solitary *Corymorpha* *Nemertesia*	
ANTHOZOA	*Corynactis*	*Alcyonium*		Small solitary *Epizoanthus* *Caryophyllia*	Med. solitary *Virgularia* *Cerianthus* *Urticina*	Large solitary *Eunicella* *Funiculina* *Pachycerianthus*
ANNELIDA	*Sabellaria spinulosa*	*Sabellaria alveolata*	*Spirorbis*	Scale worms *Nephtys* *Pomatoceros*	*Chaetopterus* *Arenicola* *Sabella*	
CRUSTACEA	Barnacles Tubiculous amphipods		*Semibalanus* Amphipods	*B. balanus* *Anapagurus* *Pisidia*	*Pagurus* *Galathea* Small crabs	*Homarus* *Nephrops* *Hyas araneus*
MOLLUSCA	*Mytilus* *Modiolus*		Small gastropod *L. neritoides* Small bivalves *Nucula*	Chitons Med. gastropod *L. littorea* *Patella* Med. bivalves *Mytilus* *Pododesmus*	Large gastropod *Buccinum* Lge bivalves *Mya, Pecten* *Arctica*	
BRACHIOPODA				*Neocrania*		
BRYOZOA	Crusts	*Pentapora* *Bugula Flustra*			*Alcyonidium* *Porella*	
ECHINO-DERMATA				*Echinocyamus* *Ocnus*	*Antedon* Small starfish Brittlestars *Echinocardium* *Aslia, Thyone*	Large starfish *Echinus* *Holothuria*
ASCIDIACEA	Colonial *Dendrodoa*			Small solitary *Dendrodoa*	Large solitary *Ascidia, Ciona*	*Diazona*
PISCES					Gobies Blennies	Dog fish Wrasse
PLANTS	Crusts, Maerl *Audouinella* Fucoids, Kelp *Desmarestia*	Foliose Filamentous			*Zostera*	Kelp *Halidrys* *Chorda* *Himanthalia*

Appendix C. Survey site descriptions

Table C1: List of biotopes assigned to each habitat at each survey site in the vicinity of the CW outfall, Wylfa Head, Llanbadrig and Point Lynas during 2015. Biotope codes and names according to the National Marine Biotope Classification (Connor *et al.*, 2004) with some exceptions (*).

Site ref.	Biotope code	Biotope name/description	No. taxa
BG1S3*	IR.MIR	Moderate energy infralittoral rock - covered in coralline algal crusts and barnacles, sparse filamentous and foliose red, green and brown algae.	16
BG1S4*	IR.MIR	Moderate energy infralittoral rock - covered in coralline algal crusts and barnacles with anemones and occasional filamentous and foliose red, green and brown algae.	10
BG1S5*	IR.MIR	Moderate energy infralittoral rock - covered in coralline algal crusts and barnacles with anemones. Frequent *Halopteris scoparia* and occasional filamentous and foliose red, green and brown algae.	22
OW1S1	IR.MIR.KR.XFoR	Dense foliose red seaweeds on moderately exposed, silted, stable, infralittoral rock, occasional *H. scoparia*. A notable absence of kelp and notably fewer taxa than OW1S2.	25
OW1S2	IR.MIR.KR.XFoR	Dense foliose red seaweeds on moderately exposed, silted, stable, infralittoral rock - with frequent *H. scoparia*. A notable absence of kelp.	45
OW2S1	IR.MIR.KR	Kelp with red seaweeds (moderate energy infralittoral rock).	48
OW3S1	IR.MIR.KR.Lhyp.Pk	*Laminaria hyperborea* park and foliose red seaweeds on moderately exposed lower infralittoral rock.	69
OW3S2	IR.HIR.KFaR.FoR	Foliose red seaweeds on exposed lower infralittoral rock.	45
OW4S1	IR.MIR.KR.Lhyp.Pk	*Laminaria hyperborea* park and foliose red seaweeds on moderately exposed lower infralittoral rock.	51
OW4S2	IR.MIR.KR.Lhyp.Pk	*Laminaria hyperborea* park and foliose red seaweeds on moderately exposed lower infralittoral rock.	41
OE1S1	IR.HIR.KFaR.FoR	Foliose red seaweeds on exposed lower infralittoral rock.	46
OE1S2	IR.MIR.KR.Lhyp.Pk	*Laminaria hyperborea* park and foliose red seaweeds on moderately exposed lower infralittoral rock.	55
OE2S1	IR.MIR.KR.Lhyp.Pk	*Laminaria hyperborea* park and foliose red seaweeds on moderately exposed lower infralittoral rock.	78
OE2S2	IR.HIR.KFaR.FoR	Foliose red seaweeds on exposed lower infralittoral rock.	60
OE3S1	IR.MIR.KR.Lhyp.Pk	*Laminaria hyperborea* park and foliose red seaweeds on moderately exposed lower infralittoral rock.	67
OE3S2	IR.HIR.KFaR.FoR	Foliose red seaweeds on exposed lower infralittoral rock.	56
OE4S1	IR.MIR.KR.Lhyp.Ft	*Laminaria hyperborea* forest and foliose red seaweeds on moderately exposed upper infralittoral rock.	39
OE4S2	IR.MIR.KR.Lhyp.Pk	*Laminaria hyperborea* park and foliose red seaweeds on moderately exposed lower infralittoral rock.	41
WH1S1	IR.MIR.KR.LhypT	*Laminaria hyperborea* on tide-swept, infralittoral rock.	80
WH1S2	IR.HIR.KFaR.FoR	Foliose red seaweeds on exposed lower infralittoral rock.	59
WH2S1	IR.MIR.KR.Lhyp.Ft	*Laminaria hyperborea* forest with foliose red seaweeds with hydroids, bryozoans and sponges on tide-swept lower infralittoral rock.	99
WH3S1	IR.MIR.KR.Lhyp.Pk	*Laminaria hyperborea* park and foliose red seaweeds on moderately exposed lower infralittoral rock.	82
WH3S2	IR.MIR.KR.Lhyp.Pk	*Laminaria hyperborea* park and foliose red seaweeds on moderately exposed lower infralittoral rock.	71
LB1S1	IR.MIR.KR.Lhyp.Ft	*Laminaria hyperborea* forest and foliose red seaweeds on moderately exposed upper infralittoral rock.	55
LB1S2	IR.HIR.KFaR.FoR	Foliose red seaweeds on exposed lower infralittoral rock.	58
LB2S1	IR.MIR.KR.Lhyp.Pk	*Laminaria hyperborea* park and foliose red seaweeds on moderately exposed lower infralittoral rock.	67
LB2S2	IR.HIR.KFaR.FoR	Foliose red seaweeds on exposed lower infralittoral rock.	49

Site ref.	Biotope code	Biotope name/description	No. taxa
LB3S1	IR.MIR.KR.LhypT	*Laminaria hyperborea* on tide-swept, infralittoral rock.	40
LB3S2	IR.MIR.KR.LhypT.Pk	*Laminaria hyperborea* park with hydroids, bryozoans and sponges on tide-swept lower infralittoral rock.	64
LB4S1	IR.MIR.KR.Lhyp.Ft	*Laminaria hyperborea* forest and foliose red seaweeds on moderately exposed upper infralittoral rock.	36
LB4S2	IR.MIR.KR.Lhyp.Pk	*Laminaria hyperborea* park and foliose red seaweeds on moderately exposed lower infralittoral rock.	54
LB5S1	IR.MIR.KR.LhypT	*Laminaria hyperborea* on tide-swept, infralittoral rock.	55
LB5S2	IR.HIR.KFaR.FoR	Foliose red seaweeds on exposed lower infralittoral rock.	83
LB6S1	IR.MIR.KR.LhypT	*Laminaria hyperborea* on tide-swept, infralittoral rock.	74
LB6S2	IR.MIR.KR.LhypT.Pk	*Laminaria hyperborea* park with hydroids, bryozoans and sponges on tide-swept lower infralittoral rock.	65
PL1S1	IR.MIR.KR.LhypT.Pk	*Laminaria hyperborea* park with hydroids, bryozoans and sponges on tide-swept lower infralittoral rock.	88
PL1S2	IR.MIR.KR.LhypT.Pk	*Laminaria hyperborea* park with hydroids, bryozoans and sponges on tide-swept lower infralittoral rock.	72
PL2S1	IR.MIR.KR.LhypT.Pk	*Laminaria hyperborea* park with hydroids, bryozoans and sponges on tide-swept lower infralittoral rock.	103
PL2S2	CR.HCR.XFa	Mixed faunal turf communities	45

* - Biotope codes for some of the impacted habitats were not adequately covered by those listed by Connor *et al*. (2004). These habitats have been given a high level classification that is considered to be appropriate for the physical environment; however, additional descriptive text has been added at these sites.

BG1 – Close to the CW outfall 2015

Situation	Very close to the outfall (ranging from ~35-75m).
Physical Parameters	Survey depth: ~2.0m acd[6] to 2.2m bcd Tidal streams: Moderately strong Wave exposure: Moderately exposed Ambient water temperature was noticeably higher at the BG sites than other sites surveyed. It was also noted that the mixing of the water caused rapid changes in the water temperature.
Habitat 3 – BG1S3	A mix of steeply sloping and vertical bedrock and large boulder reef with vertical sections at a distance of ~35m from outfall, at a depth from chart datum to approximately 2.2m bcd. The community was dominated by barnacles and crustose red algae. The appearance of several filamentous and foliose algae gave a noticeably different look to this habitat. Algae recorded included *Halopteris scoparia*, *Rhodymenia holmesii*, *Corallina officinalis,* filamentous brown and green algae. Many bass present at this point as well as a large lobster and *Palaemon* prawn.

[6] acd – above chart datum.

Habitat 4 – BG1S4	A mix of steeply sloping and vertical bedrock and large boulder reef with vertical sections at a distance of ~50m from the outfall at chart datum to ~2.2m bcd. This habitat was again characterised by dominant cover of encrusting coralline algae and barnacles with *Actinothoe sphyrodeta.* Although fewer red algae were recorded at this point this might have been owing to turbulent water and stronger currents at this point distracting the surveyors.
Habitat 5 – BG1S5	A mix of steeply sloping and vertical bedrock and large boulders at a distance of ~75m from the outfall at 2.0m acd to 2.2m bcd. The bedrock and boulders were silt covered and the angular boulders create overhangs and steep sides. Upper faces of boulders and bedrock were dominated by encrusting red algae, barnacles and *Actinothoe sphyrodeta* along with an increasing number of foliose red and brown alga (e.g. *Phyllophora truncata, P. crispa and P. pseudoceranoides, Callophyllis laciniata* and *Dictyota dichotoma*). The invasive green alga *Codium fragile* was again recorded here in 2015.

Coralline algal crusts, barnacles, *Actinothoe sphyrodeta* and sparse algae close to BG1S4.

Halopteris scoparia recorded in BG1S3 and BG1S5.

Schooling bass observed throughout the site, particularly at BG1S3 (image from 2012).

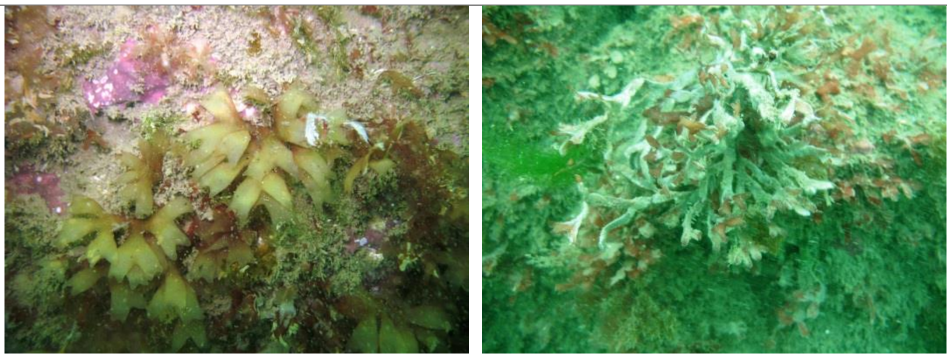
Increasing algal cover and dense, silt-covered barnacles in BG1S4.

Example of BG1S5 with more dense red algal cover over a layer of encrusting red algae.

OW1 Outfall West 2015

Situation	Coastline ~100m to the west of the outfall
Physical Parameters	Survey depth: 1.2m acd to 3.3m bcd Tidal streams: Moderately strong Wave exposure: Moderately exposed
Habitat 1 – OW1S1	Upper infralittoral upper faces of bedrock outcrops at bottom of vertical wall from 1.2m acd to 0.8m bcd. Covered in dense red and brown foliose algae and kelp was absent. *Halopteris scoparia* and *Halopteris filicina* were frequently recorded as were *Dictyota dichotoma* and *Chondrus crispus*. The anemone *Actinothoe sphyrodeta* was recorded as 'rare'. The last few metres of transect showed noticeable and abrupt decreases in red and brown algae. *Anemonia viridis* was recorded in 2011 and 2012 but absent in 2015.
Habitat 2 – OW1S2	Very steep and vertical bedrock 1.2m acd to 3.3m bcd. 'Occasional' *Dictyota dichotoma* and 'frequent' *Halopteris scoparia* and *Rhodymenia holmesii*. Cirripedia spp. were 'abundant'.

Halopteris spp. dominating the habitat.



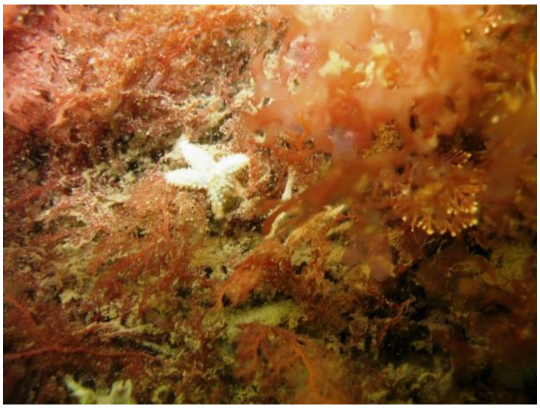
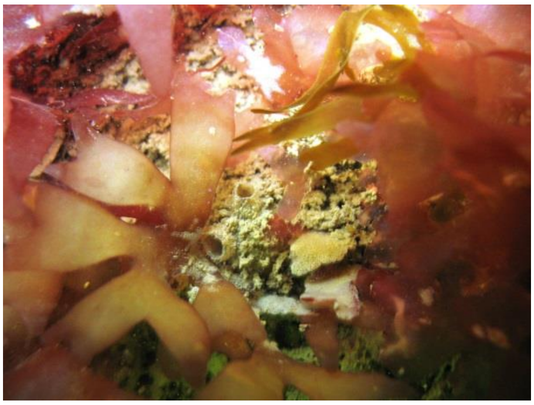
Rhodymenia pseudopalmata and *Phyllophora pseudoceranoides* growing on vertical and upward facing rock surfaces.

OW2 Outfall West 2015

Situation	Coastline ~170m to the west of the outfall
Physical Parameters	Survey depth: 2.3m bcd to 4.0m bcd Tidal streams: Moderately strong Wave exposure: Moderate
Habitat 1 – OW2S1	Lower infralittoral bedrock reef with upward-facing, very steep and vertical surfaces. Kelp park (*Laminaria hyperborea*) present with heavily silted diverse community of red and brown algae e.g. *Cryptopleura ramosa*, *Halopteris filicina*, *Calliblepharis ciliata*, *Delessaria sanguinea*, *Heterosiphonia plumosa*, *Polysiphonia elongata* and *Dictyota dichotoma* with less *Halopteris scoparia* than OW1 and BG1. Increasing faunal cover of anemones, bryozoans and tunicates, sponges beginning to appear (*Sycon ciliatum* and *Leucosolenia* spp.).
No images in 2015.	

OW3 Outfall West 2015

Situation	Coastline ~250m to the west of the outfall
Physical Parameters	Survey depth: 1.2m acd to 2.8m bcd Tidal streams: Moderately strong Wave exposure: Moderate
Habitat 1 – OW3S1	Mainly upward-facing bedrock with some steep slopes from 1.2m acd to 1.8m bcd. Kelp park (*Laminaria hyperborea*) with dense understorey of red algae, particularly the species *Heterosiphonia plumosa*, *Plocamium* spp. and *Cryptopleura ramosa. Molgula* spp. was ‘occasional’.

Habitat 2 – OW3S2	Mainly steeply sloping to vertical bedrock. Depth ranged from 0.3m to 2.8m bcd. Red foliose algae with predominant cover of *Heterosiphonia plumosa*, *Schottera nicaeensis*, *Plocamium* spp. and *Cryptopleura ramosa.* Tunicates *Clavelina lepadiformis* and *Aplidium punctum* were 'frequent'.
	
Leptasterias muelleri amongst mixed red algae – *Plocamium* spp., *Cryptopleura ramosa* and *Corallina officinalis.*	*Molgula* spp. amongst red algal turf.

OW4 Outfall West 2015

Situation	Coastline ~280m to the west of the outfall
Physical Parameters	Survey depth: 0.3m bcd to 3.3m bcd Tidal streams: Moderately strong Wave exposure: Moderate
Habitat 1 – OW4S1	Infralittoral bedrock habitat of horizontal faces with some steep to vertical sections at 0.3m to 1.8m bcd. Kelp park (*Laminaria hyperborea*) with dense understorey of mixed red algae dominated by *Plocamium* spp. and foliose red algae. Abundant *Balanus* spp.
Habitat 2 – OW4S2	From 1.8 to 3.3m bcd. Upper infralittoral vertical bedrock with kelp park and red algae dominated by *Meredithia microphylla* and *Schottera nicaeensis*. Dense patches of barnacles and tunicates including *Molgula* spp., *Clavelina lepadiformis* and *Aplidium punctum*.

 *Halichondria* sponge, *Henricia* spp. seastar and mixed red algae.	 Kelp park and red algal turf.

OE1 Outfall East 2015

Situation	Coastline ~140m to the east of the outfall
Physical Parameters	Survey depth: 0.6m acd to 1.9m bcd Tidal streams: Moderately strong (due to outfall) Wave exposure: Moderate
Habitat 1 – OE1S1	Upper infralittoral upward facing and some steeply sloping bedrock from 0.6m acd to 0.9m bcd with kelp forest in places. Thick covering of relatively diverse foliose red algae with some browns though several species were notably abundant including *Plocamium* spp. and *Heterosiphonia plumosa*. Frequently recorded fauna consisted of *Balanus* spp. and *Electra pilosa*.
Habitat 2 – OE1S2	Upper infralittoral vertical rock faces from 0.6m bcd to 1.9m bcd at which point bed consisted of cobbles and boulders. Constant current in area. Kelp park habitat with characterising understorey algae of *Schottera nicaeensis*, *Meredithia microphylla*, *Plocamium* spp., *Delessaria sanguinea*, and *Dictyota dichotoma*. Fauna mainly composed of ascidians (specifically *Aplidium punctum* and *Clavelina lepadiformis*), *Balanus* spp. and *Electra pilosa.*

 Mixed red algal turf.	 Mixed red algal turf.

OE2 Outfall East 2015

Situation	Coastline ~175m to the east of the outfall
Physical Parameters	Survey depth: 0.9m bcd to 4.8m bcd Tidal streams: Weak Wave exposure: Moderate
Habitat 1 – OE2S1	Upper infralittoral upward-facing and some steeply sloping bedrock from 0.9m bcd to 3.2m bcd covered by *Laminaria hyperborea* park. Dense understorey of *Plocamium* spp*.*, *Heterosiphonia plumosa*, *Cryptopleura ramosa*, *Acrosorium venulosum* and *Delessaria sanguinea* with dense *Electra pilosa* on the red algae and *Balanus* sp. on the bedrock. Increasing sponge fauna including *Leucosolenia* spp., *Grantia* spp. and *Sycon ciliatum*.
Habitat 2 – OE2S2	Upper infralittoral vertical bedrock with some overhangs from 2.0m bcd to 4.8m bcd dominated by red foliose algae, namely *Schottera nicaeensis* and *Meredithia microphylla* though fewer species than Habitat 1 and increased bryozoans (*Bugula* spp., *Electra pilosa*, Crisiidae spp.) and sponges (*Dysidea fragilis*, *Hemimycale columella*, *Hymeniacidon perlevis*) with frequent tunicates (*Clavelina lepadiformis* and *Aplidium punctum*).
 Red algae understorey – *Plocamium* sp.	 *Barnacles* in Habitat 1.

OE3 Outfall East 2015

Situation	Coastline ~230m to the east of the outfall
Physical Parameters	Survey depth: 2.1m acd to 2.5m bcd Tidal streams: Moderately strong Wave exposure: Moderate
Habitat 1 – OE3S1	Infralittoral upward-facing and steeply sloping bedrock from 2.1m acd to 0.4m bcd. Kelp park (*Laminaria hyperborea*) with dense red algae (*Heterosiphonia plumosa, Cryptopleura ramosa* and *Plocamium* spp.). Sparse fauna with the exception of occasional dense patches of barnacles, *Dendrodoa*/*Polycarpa* spp. and *Clavelina lepadiformis*.
Habitat 2 – OE3S2	Lower infralittoral steeply sloping bedrock from 0.1m bcd to 2.5m bcd with steep and vertical faces. Dense red algae predominantly comprising *Plocamium* spp., *Furcellaria lumbricalis* and *Schottera nicaeensis.* Between the heavily silted algae were dense mats of *Dendrodoa/Polycarpa* spp. A variety of sponges was recorded, though none in abundance.

Lobster amongst red algal turf in kelp park.

Dendrodoa/*Polycarpa* sp. tunicates.

OE4 Outfall East 2015

Situation	Coastline ~340m to the east of the outfall
Physical Parameters	Survey depth: 0.4m acd to 1.1m bcd Tidal streams: Moderately strong Wave exposure: Moderate
Habitat 1 – OE4S1	Upper infralittoral bedrock with upward-facing to vertical sections from 0.4m acd to 1.1m bcd. Kelp forest (*Laminaria hyperborea*) on upward facing bedrock with a dense understorey of red algae including *Heterosiphonia plumosa, Cryptopleura ramosa, Phyllophora pseudoceranoides* and *Plocamium* spp. Much *Electra pilosa* and *Membranipora membranacea* were recorded on the algae. Sparse fauna.

Habitat 2 – OE4S2	Lower infralittoral steep to vertical bedrock from 0.1m bcd to 2.6m bcd. Sparse kelp park dominated by foliose red algae including *Cryptopleura ramosa*, *Schottera nicaeensis* and *Meredithia microphylla.* Dense turfs of ascidians, barnacles and bryozoans with sparse sponges.
No images in 2015.	

WH1 Wylfa Head 2015

Situation	Coastline ~465m to the east of the outfall
Physical Parameters	Survey depth: 1.6m bcd to 3.1m bcd Tidal streams: Strong Wave exposure: Moderately exposed
Habitat 1 – WH1S1	Sublittoral fringe/upper infralittoral moderately sloping bedrock from 1.6m bcd to 3.1m bcd. *Laminaria hyperborea* with dense cover of foliose red algae dominated by *Plocamium* spp. Fauna not particularly abundant though a variety of sponges, hydroids and bryozoans was recorded. Barnacles and coralline algal crusts were common on the substratum.
Habitat 2 – WH1S2	Lower infralittoral steep to vertical bedrock from 3.1m bcd to 4.6m bcd. Bedrock covered by dense mats of *Schottera nicaeensis* and commonly recorded *Plocamium* spp., *Meredithia microphylla*, *Erythroglossum laciniatum* and *Dictyota dichotoma*. Greater faunal diversity than Habitat 1 with a variety of bryozoans, ascidians, sponges (particularly *Leucosolenia* spp.) and hydroids.

Aplidium punctum, red algal turf and bryozoan turf.

Halarachnion ligulatum and *Plocamium* spp. in red algal turf.

WH2 Wylfa Head 2015

Situation	Coastline ~535m to the east of the outfall
Physical Parameters	Survey depth: 1.4m bcd to 5.3m bcd Tidal streams: Strong Wave exposure: Moderately exposed
Habitat 1 – WH2S1	Lower infralittoral mainly upward facing bedrock from 1.4m bcd to 5.3m bcd. *Laminaria hyperborea* forest with dense red algae dominated by *Plocamium* spp., *Clavelina lepadiformis*, *Aplidium punctum* and *Molgula* sp. Fairly diverse range of fauna with notable abundance of *Bugula* spp., *Antedon bifida*, *Sycon ciliatum* and *Electra pilosa*.

Aplidium punctum, Leucosolenia sp*.,* crisiids and red algae.

Bugula flabellata, *Alcyonium digitatum*, *Antedon bifida* and red algae.

Aplidium punctum and *Antedon bifida.*

WH3 Wylfa Head 2015

Situation	Coastline ~625m to the east of the outfall
Physical Parameters	Survey depth: Shallow 1.8m bcd to 5.1m bcd Tidal streams: Strong Wave exposure: Moderately exposed
Habitat 1 – WH3S1	Lower infralittoral upward facing and some steeply sloping bedrock from 1.8m bcd to 3.3m bcd. *Laminaria hyperborea* park with dense understorey of red algae, particularly *Plocamium* spp., *Heterosiphonia plumosa* and *Delesseria sanguinea.* Coralline algal crusts were prevalent on the substratum. The brown algae *Dictyota dichotoma* and *Halopteris filicina* were also commonly seen. Diverse fauna was dominated by barnacles, bryozoans, tunicates and *Antedon bifida.*
Habitat 2 – WH3S2	Lower infralittoral very steep bedrock walls with some vertical and upward-facing sections from 3.3m bcd to 5.1m bcd. *Laminaria hyperborea* park though more sparse than Habitat 1 and a less dense understorey of red algae though still dominated by *Plocamium* spp. and *Heterosiphonia plumosa*. Again, diverse fauna was dominated by barnacles, bryozoans, tunicates and *Antedon bifida.* Occasional *Flustra foliacea* and *Alcyonium digitatum.*

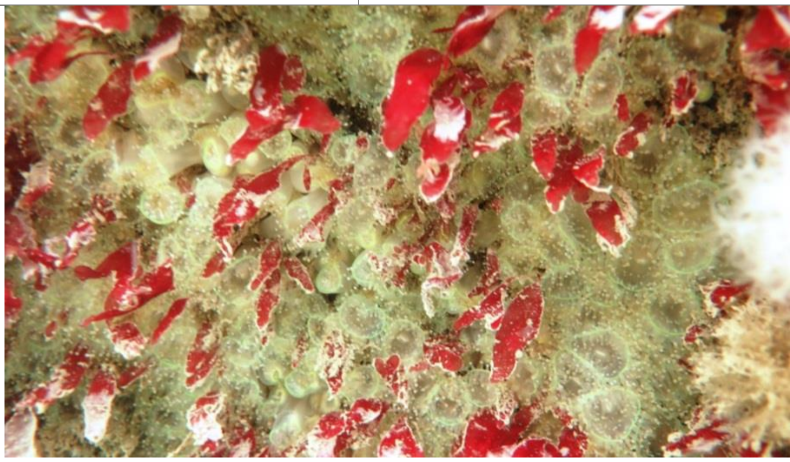
Mixed faunal and algal turf including *Heterosiphonia plumosa*, *Delessaria sanguinea*, *Aplidium punctum*, *Antedon bifida* and *Halecium halecinum*.

 *Facelina auriculata* on red algal turf.	 Mixed algal and faunal turf on vertical surfaces.

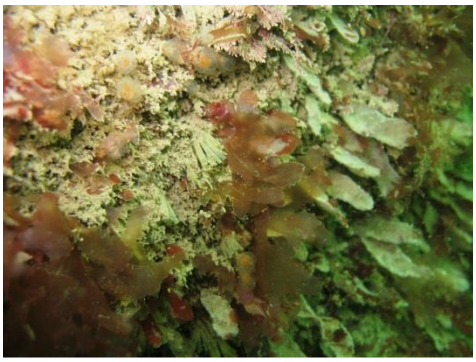
LB1 Llanbadrig 2015

Situation	Coastline ~2.8km to the east of the outfall
Physical Parameters	Survey depth: 0.5m acd to 2.9m bcd Tidal streams: Moderately strong Wave exposure: Moderately exposed
Habitat 1 – LB1S1	Sublittoral fringe of very steep and vertical wave surged bedrock with some overhangs from 0.5m bcd to 2.7m bcd. Kelp forest with coralline algae and understorey including *Plocamium* spp., *Phyllophora pseudoceranoides, Phycodrys rubens* and *Cryptopleura ramosa*. Generally sparse fauna with dense crisiid turf, encrusting bryozoans and patches of *Dendrodoa/Polycarpa* spp. tunicates and the sponges *Grantia* spp., *Sycon ciliatum* and *Leucosolenia* spp.
Habitat 2 – LB1S2	Upper infralittoral very steep sloping bedrock reef with some overhangs from 0.3m bcd to 3.9m bcd. Red algae dominated by *Plocamium* spp.*, Schottera nicaeensis* and *Phyllophora pseudoceranoides. Dendrodoa/Polycarpa* sp. mats with *Electra pilosa* coating much of the red algae. Dense crisiid turf. *Corynactis viridis* common on vertical and overhangs. *Grantia* spp., *Sycon ciliatum* and *Leucosolenia* spp. sponges were also present.

 Red algae and mixed faunal turf of hydroids,	 Red algae, *Dendrodoa/Polycarpa* spp., *Grantia*

tunicates and bryozoans.	spp., and *Alcyonidium diaphanum*.
 *Schottera nicaeensis* and *Corynactis viridis* on vertical bedrock.	

LB2 Llanbadrig 2015

Situation	Coastline ~2.9km to the east of the outfall
Physical Parameters	Survey depth: 1.0m acd to 3.4m bcd Tidal streams: Moderately strong Wave exposure: Moderately exposed
Habitat 1 – LB2S1	Lower infralittoral upward faces and slopes of heavily silted boulders from 1.0m acd to 3.4m bcd. Dominant cover of red algae (*Plocamium* spp. and *Heterosiphonia plumosa*) within *Laminaria hyperborea* kelp park. Bryozoan (crisiids and crusts), sponges (*Grantia* spp., *Sycon* spp. and *Leucosolenia* sp.) and tunicates (*Dendrodoa/Polycarpa* spp.) covered rock with intermittent patches of barnacles and coralline crusts.
Habitat 2 – LB2S2	Lower infralittoral verticals and overhangs of heavily silted boulders from 1.0m acd to 3.4m bcd. Algae more sparse and dominated by *Schottera nicaeensis*. Substratum covered with sponges, tunicates, barnacles and bryozoans.
 *Leucosolenia* spp., tunicates, red algae and	

bryozoan turf.	Red algae, tunicates and bryozoan turf.

Coralline algae and sponge crusts with bryozoan turf.

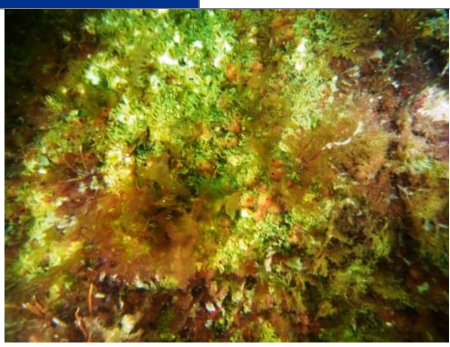
LB3 Llanbadrig 2015

Situation	Coastline ~2.9km to the east of the outfall
Physical Parameters	Survey depth: 0.3m bcd to 4.3m bcd Tidal streams: Moderately strong Wave exposure: Moderately exposed
Habitat 1 – LB3S1	Upper infralittoral steeply sloping and upward-facing bedrock from 0.3m bcd to 2.3m bcd. Abundant *Laminaria hyperborea* forest with a dense understorey of red algae (particularly *Plocamium* spp*., Delessaria sanguinea, Cryptopleura ramosa* and *Chondrus crispus*). Sparse fauna of sponges, hydroids, ascidians and bryozoans. Dense barnacles beneath algal turf.
Habitat 2 – LB3S2	Lower infralittoral vertical and steep bedrock with some overhangs from 1.3m bcd to 4.3m bcd. Kelp (*Laminaria hyperborea*) park with a diverse blend of fauna and flora. Foliose reds including *Schottera nicaeensis* and *Meredithia microphylla* were the dominant flora along with *Dictyota dichotoma.* A mixture of bryozoan turf and diverse sponge community dominated the fauna.

 Mixed faunal and algal turf – sponge, tunicates, bryozoans and *Henricia* spp.	 Mixed faunal turf – sponge, tunicates and bryozoans.

LB4 Llanbadrig 2015

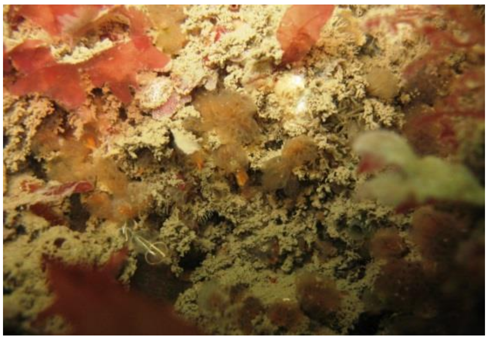
Situation	Coastline ~3km to the east of the outfall
Physical Parameters	Survey depth: 0m bcd to 1.4m bcd Tidal streams: Strong Wave exposure: Moderately exposed
Habitat 1 - LB4S1	Upper infralittoral upward facing bedrock with some vertical sections at 0m bcd to 1.4m bcd. Kelp forest (*Laminaria hyperborea*) with dense stands of *Plocamium* spp. and *Chondrus crispus.* Sparse fauna but dense patches of *Balanus* sp. and coralline algal crusts.
Habitat 2 – LB4S2	Upper infralittoral bedrock at 0.9m bcd to 2.9m bcd. Variable gradient wall (40° to 90°) with some upward facing sections and kelp park (*Laminaria hyperborea*) and dense cover of *Plocamium* spp., *Schottera nicaeensis, Phycodrys rubens* and occasional *Delesseria sanguinea.* More diverse fauna of bryozoans and tunicates but other taxa remained sparse.

 Dense *Balanus* spp. and *Dendrodoa/Polycarpa* spp. amongst red algae.	 Mixed faunal and algal turf on a vertical wall.

LB5 Llanbadrig 2015

Situation	Coastline ~3.2km to the east of the outfall
Physical Parameters	Survey depth: 0.7m acd to 2.6m bcd Tidal streams: Strong Wave exposure: Moderately exposed
Habitat 1 – LB5S1	*Laminaria hyperborea* forest on steeply sloping bedrock to a depth of 1.8m bcd. Dense red algae beneath and between the kelp predominantly consisting of *Plocamium* spp*., Chondrus crispus, Phycodrys rubens* and *Cryptopleura ramosa*. Fauna consists of bryozoan/hydroid turfs and sparse sponges.
Habitat 2 – LB5S2	Very steep and near-vertical bedrock at a depth of 0.8m to 2.6m bcd dominated by the red algae *Schottera nicaeensis, Erythroglossum laciniatum* and *Delessaria sanguinea* with abundant coralline algal crusts*.* Numerous patches of hydroids, bryozoans, tunicates and sponges. Much of the red algae were covered by *Electra pilosa* and the bedrock wall dotted with the soft coral *Alcyonium digitatum*.

Red algal turf and *Symphodus melops* just below kelp forest habitat.



Mixed algal and faunal turf on a vertical wall with tunicates and bryozoans.

LB6 Llanbadrig 2015

Situation	Coastline ~3.3km to the east of the outfall
Physical Parameters	Survey depth: 1.3m acd to 3.5m bcd Tidal streams: Moderately strong Wave exposure: Moderately exposed
Habitat 1 – LB6S1	Upper infralittoral upward-facing bedrock with some steep sections from 1.3m acd to 0.7m bcd. Dense kelp forest (*Laminaria hyperborea*) with very dense *Plocamium* spp*., Cryptopleura ramosa, Phyllophora pseudoceranoides* and *Delessaria sanguinea* and coralline crusts. Range of fauna included hydroids (*Tubularia indivisa, Eudendrium* spp*., Nemertesia antennina*) and bryozoans (especially *Electra pilosa*), sparse sponges and several species of ascidian within the algae beds.

Habitat 2 – LB6S2	Lower infralittoral vertical and overhanging bedrock at 0.7m acd to 3.5m bcd covered with very sparse kelp (*Laminaria hyperborea*) dense red algae dominated by *Schottera nicaeensis* and *Delessaria sanguinea* and coralline crusts. Fauna included hydroids (*Eudendrium* spp., *Nemertesia antennina*) and bryozoans (especially *Electra pilosa* and dense crisiids), sparse sponges and several species of tunicate including *Clavelina lepadiformis*.
No images in 2015.	

PL1 Point Lynas 2015

Situation	Coastline ~13.5km to the east of the outfall
Physical Parameters	Survey depth: 0.2m bcd to 3.9m bcd Tidal streams: Moderately strong Wave exposure: Moderately exposed
Habitat 1 – PL1S1	Upper infralittoral upward facing to steeply sloping bedrock at 0.2m bcd to 3.9m bcd. Dense kelp park (*Laminaria hyperborea*) with very mixed algae and faunal understorey appearing to have more wave exposure than other sites as indicated by the presence of *Alaria esculenta*. Main algal understorey species included *Plocamium* spp., *Erythroglossum laciniatum* and *Corallina officinalis*. Coralline crusts, barnacles and crisiids were common with occasional sponges, bryozoans and tunicate species.
Habitat 2 – PL1S2	Lower infralittoral bedrock at 2.4m bcd to 3.9m bcd. Vertical bedrock with some overhangs and steeply sloping sections. Kelp park (*Laminaria hyperborea*) with mixed algal and faunal understorey *Plocamium* spp., *Schottera nicaeensis, Meredithia microphylla* and coralline crusts with increased quantities of crisiids, *Bugula* spp. and *Scrupocellaria* spp. Range of other fauna included sponges (including *Haliclona occulata*) and bryozoans and several species of tunicate, particularly *Aplidium punctum* and dense barnacle patches.

Scyliorhinus canicula in kelp park habitat with mixed red and coralline algae and bryozoan turf.

Patch of dense *Plocamium* spp. turf in kelp park habitat.

	
Cirripedia spp. *Corallina officinalis*, *Plocamium* spp. and *Heterosiphonia plumosa* in kelp park.	*Symphodus melops* over mixed algal and faunal turf in kelp park.

PL2 Point Lynas 2015

Situation	Coastline ~13.5km to the east of the outfall
Physical Parameters	Survey depth: 2.5m bcd to 5.6m bcd Tidal streams: Moderately strong Wave exposure: Moderately exposed
Habitat 1 – PL2S1	Upper infralittoral steeply sloping with some upward facing bedrock at 2.5m bcd to 5.6m bcd. Dense kelp park (*Laminaria hyperborea*) with very mixed algae and faunal understorey but no *Alaria esculenta* as at PL1. Main algal understorey species included *Plocamium* spp. and *Corallina officinalis*. Coralline crusts, barnacles and crisiids were common with occasional sponges, bryozoans and tunicate species. Common *Alcyonium digitatum* present in this habitat.
Habitat 2 – PL2S2	Lower infralittoral vertical bedrock with some overhangs, at 2.5m bcd to 5.6m bcd. Vertical bedrock covered with sparse red algae dominated by *Brongniartella byssoides*, *Schottera nicaeensis* and *Meredithia microphylla*. Dense crisiid turf, frequent – occasional *Clavelina lepadiformis* and *Aplidium punctum*. Range of other fauna included sponges (*Leucosolenia* spp.) and bryozoans (especially *Bugula* spp.) and hydroids (*Nemertesia antennina*). The rarely seen nudibranch, *Okenia elegans* was also recorded at this site.

	
Kelp park habitat.	Mixed algal and faunal turf.

 Bryozoan, sponge and hydroid turf.	 *Okenia elegans* amongst red algae.

Appendix D. Survey site distances from outfall

Table D1: Sites surveyed in 2011, 2012 and 2015 and their approximate distance (km) from the CW outfall.

Site	2011	2012	2015
BG1S1	0.035	0.021	n/a
BG1S2	0.050	0.028	n/a
BG1S3	0.067	0.032	0.035
BG1S4	n/a	0.058	0.050
BG1S5	n/a	0.072	0.075
OW1	0.099	0.099	0.100
OW2	0.139	0.157	0.170
OE1	0.142	0.102	0.140
OE2	0.190	0.193	0.175
OE3	0.230	0.220	0.230
OW3	0.259	0.231	0.250
OW4	0.319	0.308	0.280
OE4	0.330	0.333	0.340
WH1	0.465	0.465	0.465
WH2	0.535	0.535	0.535
WH3	0.645	0.645	0.625
LB1	2.8	2.8	2.8
LB2	2.9	2.9	2.9
LB3	2.9	2.9	2.9
LB4	3.0	3.0	2.9
LB5	3.2	3.2	3.2
LB6	3.3	3.3	3.3
PL1	n/a	n/a	13.5
PL2	n/a	n/a	13.5

Appendix E. Subtidal Taxa List for 2015

Porifera
Clathrina coriacea
Leucosolenia spp.
Sycon ciliatum
Grantia spp.
Clathrina lacunosa
Pachymatisma johnstonia
Tethya citrina
Suberites carnosus
Suberites spp.
Polymastia boletiformis
Polymastia mamillaris
Polymastia penicillus
Cliona celata
Stelligera rigida
Stelligera stuposa
Halichondria spp.
Halichondria panicea
Hymeniacidon perlevis
Mycale spp.
Amphilectus fucorum
Phorbas fictitius
Hemimycale columella
Myxilla incrustans
Iophon spp.
Raspailia ramosa
Haliclona occulata
Haliclona viscosa
Dysidea fragilis
Porifera indet. (crusts)
Porifera indet.
Porifera A (slimy indet.)
Microciona spp.
Dercitus bucklandi
Cnidaria
Aurelia aurita
Tubularia spp.
Eudendrium spp.
Halecium halecinum
Halecium beanii
Aglaophenia spp.
Kirchenpaueria pinnata
Nemertesia antennina
Nemertesia ramosa
Plumularia setacea
Diphasia spp.
Hydrallmania falcata
Sertularella polyzonias
Sertularella spp.
Sertularia argentea
Obelia spp.
Sertularella gaudichaudi
Hydroid indet.
Garveia nutans
Dynamena pumila
Laomedea spp.
Sarcodictyon roseum
Alcyonium digitatum
Cerianthus lloydii
Epizoanthus couchii
Isozoanthus sulcatus
Actinia equina
Urticina felina
Metridium senile
Sagartia elegans
Cereus pedunculatus
Actinothoe sphyrodeta
Corynactis viridis
Caryophyllia smithii
Coryne muscoides
Platyhelminthes
Prostheceraeus vittatus
Annelida
Polychaeta indet.
Sabellaria spinulosa
Terebellidae indet.
Bispira volutacornis
Sabella spp.
Sabella pavonina
Pomatoceros spp.
Sabellaridae indet.
Eulalia viridis
Pycnogonida
Pycnogonid spp.
Crustacea
Cirripedia spp.
Mysidae spp.
Amphipoda indet. (tubes)
Caprellidae indet.
Caridea indet.
Palaemon serratus
Homarus gammarus
Pagurus spp.
Galathea spp.
Galathea strigosa
Maja squinado
Cancer pagurus
Necora puber
Carcinus maenas
Xantho spp.
Mollusca
Helcion pellucidum
Gibbula cineraria
Calliostoma zizyphinum
Trivia spp.
Nucella lapillus
Ocenebra erinacea
Buccinum undatum
Nassarius reticulatus
Patella spp.
Rissoa spp.
Tritonia lineata
Doto spp.
Polycera quadrilineata
Limacia clavigera
Doris pseudoargus
Janolus cristatas
Coryphella sp.
Flabellina pedata
Facelina auriculata
Facelina bostoniensis
Rostanga rubra
Okenia elegans
Chlamys spp.
Anomia spp.
Bryozoa
Crisiidae indet.
Alcyonidium diaphanum
Vesicularia spinosa
Membranipora membranacea
Electra pilosa
Flustra foliacea
Chartella papyracea
Bugula flabellata
Bugula plumosa
Bugula turbinata
Bicellariella ciliata
Scrupocellaria spp.
Cellaria spp.
Cellepora pumicosa
Bryozoa indet. (crusts)
Smittina spp.
Phoronida
Phoronis spp.
Echinodermata
Antedon bifida
Asterina gibbosa

Asterina phylactica
Crossaster papposus
Henricia spp.
Asterias rubens
Leptasterias muelleri
Ophiura spp.
Ophiuroidae indet.
Pawsonia saxicola
Psammechinus linearis
Ocnus lacteus
Tunicata
Clavelina lepadiformis
Pycnoclavella aurilucens
Pycnoclavella stolonialis
Polyclinidae indet.
Polyclinum aurantium
Morchellium argus
Sidnyum turbinatum
Sidnyum spp.
Aplidium punctum
Didemnidae indet.
Didemnum maculosum
Diplosoma spongiforme
Lissoclinum perforatum
Ciona intestinalis
Corella parallelogramma
Ascidia conchilega
Ascidia mentula
Ascidia virginea
Polycarpa/Dendrodoa spp.
Botryllus schlosseri
Botrylloides leachii
Molgula spp.
Perophora listeri
Euchordata: Pisces
Scyliorhinus canicula
Pollachius pollachius
Taurulus bubalis
Crenilabrus melops
Ctenolabrus rupestris
Centrolabrus exoletus
Labrus bergylta
Parablennius gattorugine
Thorogobius ephippiatus
Gadus morhua

Dicentrarchus labrax
Rhodophyta
Audouinella spp.
Asparagopsis armata
Bonnemaisonia asparagoides
Palmaria palmata
Rhodophyta indet. (crust)
Corallinacaea indet. (crusts)
Corallina officinalis
Jania spp.
Calliblepharis ciliata
Calliblepharis jubata
Cystoclinum purpureum
Rhodophyllis divaricata
Dilsea carnosa
Furcellaria lumbricalis
Halarachnion ligulatum
Chondrus crispus
Callophyllis laciniata
Kallymenia reniformis
Meredithia microphylla
Mastocarpus stellatus
Erythrodermis traillii
Phyllophora crispa
Phyllophora pseudoceranoides
Phyllophora truncata
Schottera nicaeensis
Polyides rotundus
Plocamium spp.
Rhodymenia holmesii
Rhodymenia pseudopalmata
Rhodymenia ardissonei
Lomentaria articulata
Lomentaria orcadensis
Lomentaria clavellosa
Gastroclonium ovatum
Ceramium spp.
Halurus flosculosus
Plumaria plumosa
Pterothamnion plumula
Ptilota gunneri
Acrosorium venulosum
Apoglossum ruscifolium
Cryptopleura ramosa
Delesseria sanguinea

Drachiella heterocarpa
Drachiella spectabilis
Erythroglossum laciniatum
Haraldiophyllum bonnemaisonii
Hypoglossum hypoglossoides
Membranoptera alata
Nitophyllum punctatum
Phycodrys rubens
Heterosiphonia plumosa
Brongniartella byssoides
Polysiphonia sp.
Polysiphonia elongata
Polysihonia stricta
Rhodomela confervoides
Anotrichium furcellatum
Heterosiphonia japonica
Osmundea spp.
Porphyra spp.
Ochrophyta
Ectocarpaceae indet.
Halopteris filicina
Sphacelaria spp.
Halopteris scoparia
Cladostephus spongiosus
Dictyota dichotoma
Dictoya spiralis
Desmarestia aculeata
Desmarestia viridis
Desmarestia ligulata
Laminaria hyperborea
Alaria esculenta
Halidrys siliquosa
Phaeophyta indet. (crusts)
Chlorophyta
Enteromorpha spp.
Ulva lactuca
Chaetomorpha spp.
Chlorophyta indet.
Cladophora sp.
Bryopsis sp.
Derbesia marina
Codium fragile

Appendix F. Glossary

Biotope – the physical habitat and associated community of flora and fauna.

Chart datum – approximately the lowest tide level due to astronomical effects (excluding meteorological effects).

Circalittoral – subtidal zone characterised by animal-dominated communities.

General Location – a term used here to describe specific spatial clusters of survey sites e.g. Outfall Channel (BG), Outfall West (OW), Outfall East (OE), Wylfa Head (WH), Llanbadrig (LB) and Point Lynas (PL).

Holdfast – point of attachment of seaweed to hard substrate.

Infralittoral – subtidal zone characterised by plant-dominated communities.

Kelp forest – dense kelp growth in the upper infralittoral zone where canopy density can be so high that light is excluded. These habitats support a high diversity of species.

Kelp park – lower density of kelp where no continuous canopy exists and light is not excluded.

MNCR – Marine Nature Conservation Review. The MNCR was initiated to provide a comprehensive baseline of information on marine habitats and species, to aid coastal zone and sea-use management and to contribute to the identification of areas of marine natural heritage importance throughout Great Britain. The focus of MNCR work was on benthic habitats and their associated communities, which together are described as 'biotopes' in inshore areas.

Sporelings – young plants produced from a germinated spore.

Stipe – The stalk of a marine alga, most often used when describing kelp.

Turf – Dense growth of animal or plants across the substratum forming a continuous cover.