



Pembroke CCGT Power Station

Baseline Environmental Information - Monitoring in the Pembrokeshire Marine SAC – Response to IC4

Prepared for: Environment Agency

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Baseline Environmental Information, IC4

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1 Introduction

This document is submitted to meet improvement condition IC4 as stated in Table S1.3 Improvement Programme Requirements within the Pembroke Power Station Environmental Permit (no. EPR/DP3333TA). The condition requires:

- (a) *“The Operator shall submit to the Environment Agency at the Reporting Address a written report detailing the baseline environmental information obtained in accordance with pre-operational measure PO4.”*

The monitoring programme that constitutes the baseline environmental information is set out in our response to PO4a that was agreed with the Environment Agency in November 2011. Methodologies, frequencies and locations for the sampling regimes can be found in that document.

Below is a brief summary of the baseline environmental information that has been collected since 2006, all the raw data for those surveys is contained within the appendices. More detailed interpretation and data analysis can be found in the individual survey reports that are available from RWE on request.

2 Baseline Environmental Information

Since 2006 RWE has undertaken a programme of monitoring in the Milford Haven Waterway to obtain information on water quality and ecology to inform the planning and environmental permitting applications. The content of the survey programme was established having regard to discussions with Environment Agency Wales (EAW), Countryside Council for Wales and other key stakeholders, for example The Milford Haven Waterway Environmental Surveillance Group, during the course of the development of the Pembroke project.

The results of these monitoring regimes have been used to establish baseline environmental information prior to the operation of the Installation.

This has consisted of three monitoring regimes:

1. In 2006-7 surveys were undertaken in connection with the application for consent under Section 36 of the Electricity Act 1989 and deemed planning permission for Pembroke Power Station. The surveys informed the assessment of marine environmental effects presented in Chapter 6 of RWE's Consolidated Environmental Statement (CES) submitted to the then Department of Trade and Industry in July 2007. These surveys were reported in appendices included in Volume 3 of the CES.
2. Baseline aquatic ecology and marine water quality monitoring surveys began in 2006. These were undertaken to establish, in combination with other surveys, baseline conditions in the Haven over a period of several years, against which any effects of the operating power station can be assessed. This programme of surveys also informed the Appropriate Assessment documentation supporting the Environmental Permit application submitted to the Environment Agency in February 2010.

3. A variety of specific surveys have been carried out in connection with the dredging undertaken from January 2010 to April 2010 and from October 2010 to March 2011 in the approach channel to the heavy load jetty and the Cooling Water (CW) intake in Pennar Gut, and in the CW outfall channel across Pwllcrochan Flats in the main Haven. These included bathymetric surveys before and after each period of dredging, sampling and analysis of sea water in the vicinity of dredging operations to monitor re-suspension of suspended solids, and surveys of the eelgrass beds in the Pembroke River estuary. In addition, the collection of subtidal benthic data within Pennar Gut and in the body of Milford Haven Waterway has been undertaken in order to develop an understanding of the benthic invertebrate community and sediment properties around the location of works extending into the marine environment.

In order to complete baseline information, monitoring programmes continued as detailed in PO4a until the power station became operational in November 2011. These programmes are now continuing in order to provide information for comparison against that baseline.

3 Baseline Monitoring Surveys

The following baseline surveys, summarised in Table 1, have been undertaken (except where stated) systematically since 2006: –

- Marine water quality;
- Bathymetric surveys (2010 and 2011);
- Automatic Haven temperature monitoring (from April 2011);
- Intertidal and subtidal fisheries (including invertebrates);
- Intertidal ecology;
- Ichthyoplankton;
- Zooplankton and phytoplankton surveys (2006 and 2009);
- Subtidal benthic ecology (2006, 2010 - 2011);
- Eel Fyke Netting (from 2011);
- Eelgrass surveys; and
- Subtidal epifauna surveys (from 2011).

Table 1: Baseline Monitoring Survey Programme

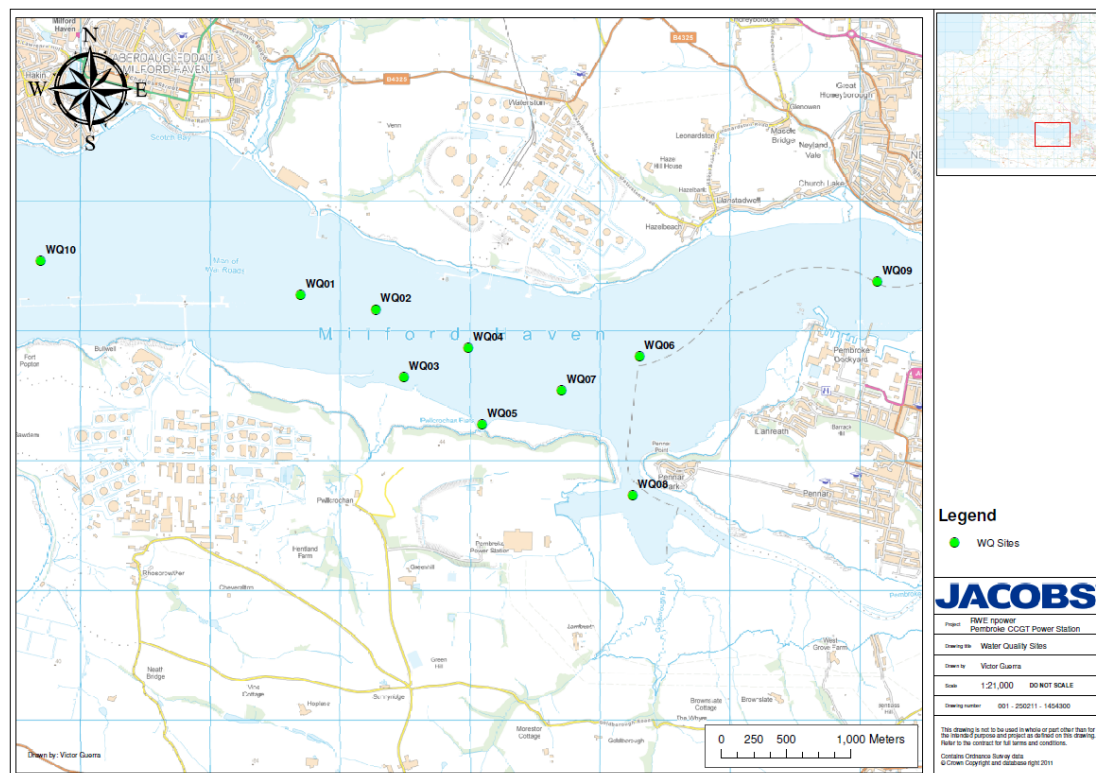
Survey	Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Water Quality	2006												
	2007												
	2008												
	2009												
	2010												
	2011												
Intertidal and subtidal fisheries (incl. invertebrates)	2006												
	2007												
	2008												
	2009												
	2010												

	2011												
Intertidal Ecology	2006												
	2007												
	2008												
	2009												
	2010												
	2011												
Ichthyoplankton	2006												
	2007												
	2008												
	2009												
	2010												
	2011												
Eelgrass	2006												
	2007												
	2008												
	2009												
	2010												
	2011												
Zooplankton / Phytoplankton	2006												
	2007												
	2008												
	2009												
	2010												
	2011												
Fyke Netting	2006												
	2007												
	2008												
	2009												
	2010												
	2011												
Subtidal Benthic	2006												
	2007												
	2008												
	2009												
	2010												
	2011												
Bathymetric (Pre and post-dredge plus monitoring surveys)	2006												
	2007												
	2008												
	2009												
	2010												
	2011												
Automatic Haven Temperature Monitoring	2006												
	2007												
	2008												
	2009												
	2010												
	2011												
Subtidal epifauna	2006												
	2007												
	2008												
	2009												
	2010												
	2011												

3.1 Marine Water Quality

A full programme of marine water quality monitoring has been undertaken at Pembroke since October 2006, the purpose being to provide data to assist in determining site-specific baseline water quality conditions in terms of both physical and chemical parameters. Surveys have continued each year on a quarterly basis to date. Survey seasons have been standardised and take place in the spring, summer, autumn and winter at 10 water quality target sites across the Haven. Figure 1 shows the location of water quality sampling points.

Figure 1: Water quality monitoring locations



The following parameters are recorded at each monitoring location:

- Temperature (°C);
- Dissolved oxygen (% saturation and mg l⁻¹);
- Conductivity (µS cm⁻¹);
- Salinity; and,
- Redox potential (mV).

All samples are analysed by a UKAS accredited laboratory for the following:

- dissolved metals comprising, arsenic (As), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), selenium (Se), boron (B), copper (Cu), nickel (Ni) and zinc (Zn);
- seawater cations and anions including calcium (Ca), potassium (K), sodium (Na);
- chloride, bromide, fluoride, and sulphate;
- total alkalinity;

- total suspended solids (TSS);
- pH;
- conductivity;
- biological and chemical oxygen demand (BOD and COD);
- dissolved nutrients including ammoniacal nitrogen, nitrite, nitrate and orthophosphate;
- total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAH) and polychlorinated biphenyls (PCBs);
- phenols; and
- cyanide.

From August 2011, water quality samples were also analysed for antimony (Sb), calcium (Ca) and magnesium (Mg).

Water quality survey data is presented in excel spreadsheet format in Appendix 1.

3.1.1 Temperature

Lowest temperatures were consistently recorded in February (winter), ranging between 8.66°C in 2008 and 6.08 °C in 2010. Highest temperatures have always been recorded in August (summer), ranging between 16.65°C in 2008 and 18.64°C in 2009. Generally, the lowest temperatures were recorded at sites WQ08 and WQ09 and the highest at WQ05, WQ08 and WQ09. Table 2 shows minimum and maximum recorded temperatures from 2006 – 2011.

A degree of thermal stratification has been repeatedly found during August and November surveys at several sites but no more than by 1°C. Weak thermal stratification has been found at several sites in June 2011, May 2010 and May 2008. Although very weak stratification was observed at several sites in February 2011, generally no evidence of thermal stratification has been found in this calendar month.

Table 2: Minimum and maximum temperatures (°C) recorded from October 2006 to November 2011

Year	Minimum Temperature	Maximum Temperature
2011	7.99	16.96
2010	6.08	18.25
2009	7.47	18.64
2008	8.66	16.65
2006-2007	7.70	17.29

3.1.2 Salinity

During 2009 - 2011 surveys, salinity values were always lowest at site WQ09 which is located furthest up the estuary. Conversely, highest salinity values were measured for all surveys, except one, at WQ10 located nearest the mouth of the estuary. Maximum 2011 salinity values were recorded in August at sites WQ02 and WQ10, in November 2010 at site WQ10 and in 2009 in December at WQ10. In 2006 maximum salinity was recorded in November, and in October in 2006 and 2007. Minimum salinity was recorded in November in 2010 and 2011 and in December in 2009.

Minimum salinity was recorded in February in 2006 and 2008.

Strong haloclines were evident at several sites in February and November 2011 and were evident at most sites in February and November 2010. In spring and summer 2010, haloclines were present in May (WQ07, WQ08 and WQ09) and August (WQ06, WQ08 and WQ10). In 2010 this indicated a degree of stratification of the water column during the autumn and winter period which became mixed during the spring and summer months. Weaker haloclines were evident at a number of sites in both the June and August 2011 surveys. In 2009 reduced salinities in surface waters were evident in February and December; clear stratification was evident at a number of sites in August.

Salinity profiles in 2008 showed a general increase in salinity with depth. Salinity showed some fluctuations throughout the year most likely due to variations in fluvial input. Salinities from October 2006 to August 2007 ranged from a minimum in February to a maximum in October. No halocline was evident in October, February and May; however there was some evidence of stratification in August 2007. This stratification appears to be caused by fluvial input and is at its greatest following periods of heavy rainfall. Table 3 shows minimum and maximum recorded salinities from 2006 – 2011.

Table 3: Minimum and maximum salinities recorded from October 2006 to November 2011.

Year	Minimum Salinity ¹	Maximum Salinity
2011	27.40	35.08
2010	28.55	34.43
2009	24.50	34.97
2008	24.63	35.39
2006-2007	21.54	32.70

3.1.3 Redox Potential (ORP)

Although based on a relatively simple theory, Oxidation-Redox Potential (ORP) is a measurement that encounters more problems than other water quality sensors with regard to consistency between different instruments and overall accuracy. The most common problem reported with regard to ORP determination in marine environments is that readings from various instruments (sometimes with exactly the same sensor type and electronics) differ by a significant margin (50-100 mV) even though the sensors are in the same container of water (YSI, 2001). Whilst this can lead to complications in the comparison of data collected with different instruments, data from the same instrument can be readily compared. The general form of the water column profile is comparable between differing instruments although caution should be applied to data interpretation.

ORP profiles recorded in 2006 - 2011 showed no significant variation with depth at any site with values consistent with well oxygenated waters. It should be noted that in 2008 no ORP data was presented for the August survey and in 2010 ORP data was not available for the May and November surveys, the latter caused by survey results

¹ Salinity is not reported with any units, it is calculated as a ratio and is therefore unitless.

not complying with RWE's aquatic consultants internal QA. Table 4 shows minimum and maximum recorded ORP values from 2006 – 2011.

In all cases variations between surface values and seabed values were less than 100 mV. Vertical increments in the water column normally have been reported between 20 mV and 40 mV, the maximum variation recorded in June at site WQ09 (52 mV).

Table 4: Minimum and maximum ORP values recorded from October 2006 to November 2011

Year	Minimum ORP (mV)	Maximum ORP (mV)
2011	169.5	337.0
2010	127.0	296.6
2009	232	542
2008	169	646
2006-2007	60	599

3.1.4 Dissolved Oxygen (DO)

Generally, DO saturation levels recorded between October 2006 and November 2011 were high. DO saturation levels ranged between 68.8% and 136.1% between February 2009 and November 2011 with DO concentrations ranging between 6.30 mg/L⁻¹ and 11.51 mg/L⁻¹ between October 2006 and November 2011.

This indicates a well oxygenated marine environment. DO concentrations have been generally higher in the winter months when the water cools and holds more oxygen. Both DO saturation and concentration levels have been recorded in excess of existing water quality standards. Table 3 shows minimum and maximum DO values from 2006 – 2011.

Table 5: Minimum and maximum DO values (% and mg L⁻¹) recorded from October 2006 to November 2011

Year	Minimum DO		Maximum DO	
	%	mg L ⁻¹	%	mg L ⁻¹
2011	92.3	8.02	111.4	9.22
2010	95.7	7.55	136.1	11.38
2009	68.8	6.30	118	9.14
2008 ²	-	6.34	-	11.51
2006-2007	-	6.80	-	10.25

3.1.5 Water Quality Laboratory Results

Many of the chemical concentrations reported were below the minimum reporting values (MRV) set by the analysing laboratory. The MRV is a minimum concentration selected for reporting purposes which is often higher than the statistically derived method limit of detection (the lowest quantity of a substance that can be distinguished from the absence of that substance or above background noise). The

² DO saturated values were not recorded prior to February 2009.

MRV is used to provide consistency of reporting as well as an allowance for sample variation.

3.1.6 pH

All locations and depths sampled between October 2006 and November 2011 had a pH between 7.7 and 8.17. These values are typical of the value expected for Milford Haven, are within the expected range for an estuarine environment and are within the guidelines for the current Bathing Water Directive (76/160/EEC) and Shellfish Water Directive (2006/113/EC).

3.1.7 Alkalinity³

Alkalinity measured to pH 4.5 as CaCO₃ between June 2009 and November 2011 ranged between 65 mg L⁻¹ and 80 mg L⁻¹. The highest values were recorded each year in June; all recorded values fell within the normal range expected for estuarine waters. Alkalinity values from 2006 through to February 2009 were elevated above normal sea and estuarine levels ranging from 96 mg L⁻¹ to 149 mg L⁻¹. The difference between values before and after February 2009 may be due to the analytical technique used by the laboratory. Table 3 shows minimum and maximum alkalinity recorded from 2006 – 2011.

Table 6: Minimum and maximum alkalinity (mg L⁻¹) from October 2006 to November 2011

Year	Alkaline Range (mg L ⁻¹)	
2011	70.7 - 79.0	
2010	71.0 - 80.0	
2009	June - December	65.0 - 75.9
	February	116 - 126
2008	109 -138	
2006-2007	96 - 149	

3.1.8 Biological and Chemical Oxygen Demand

3.1.8.1 Biological Oxygen Demand (BOD)

BOD was determined using a 5-day test and values at most sites and depths and has been sampled from 2006 to 2011. The maximum value recorded in this period was 4.00 mg L⁻¹.

In 2011 most sites and depths sampled showed BOD levels below the MRV of 1.00mg L⁻¹ (or 2.90mg L⁻¹ in February), seven samples were reported above the MRV (between 1.0 mg L⁻¹ and 1.2 mg L⁻¹), two in June, one in August and four in November. BOD values in 2010 were below the MRV of 2.90 mg L⁻¹ except for one sample in May, which had a reported value of 3.00 mg L⁻¹. BOD values for all sites sampled between June and December 2009 were below the MRV of 2.90 mg L⁻¹. Results from the February 2009 survey ranged from 2.40 to 4.00 mg L⁻¹. BOD levels in 2008 were all below the MRV of 2 mg L⁻¹, the exception being May where values

³ Alkalinity values of seawater averages 116 mg L⁻¹ and is greater than freshwater, which can have an alkalinity value of 30 to 90 mg L⁻¹, depending on the watershed. The brackish waters of an estuary will have an expected alkalinity value between 80 mg L⁻¹ and 116 mg L⁻¹ (Ohrel and Register, 2006).

ranged between $<2 \text{ mg L}^{-1}$ and 4.0 mg L^{-1} . 2006 -2007 BOD for this sampling period ranged from below the MRV of 2 mg L^{-1} to 3 mg L^{-1} .

3.1.8.2 Chemical Oxygen Demand (COD)

COD values were reported below the MRV (300 mg L^{-1} or 600 mg L^{-1}) from June 2009 to November 2011. Before June 2009, COD values were reported to be between $<100 \text{ mg L}^{-1}$ and 257 mg L^{-1} . The only exception was being in February 2007 (990 mg L^{-1}), although results for COD in saltwater can be misleading. It is well documented that chloride ions can cause interferences during the analytical process if the solution is not diluted enough.

In 2011 COD was reported as being below the MRV⁴ of 500 mg L^{-1} (or 300 mg L^{-1} in February) at all sites and depths sampled, the exception being one sample in August where the sample was reported as above MRV, with a value of 550 mg L^{-1} .

In 2010 COD was reported as being below the MRV (600 mg L^{-1}) in August and November, and below the MRV (300 mg L^{-1}) in February and most samples in May. Five samples in May were reported between 310 mg L^{-1} and 320 mg L^{-1} . In 2009 COD was reported as being below the MRV (600 mg L^{-1}) in June and August and ranged between $<240 \text{ mg L}^{-1}$ to 380 mg L^{-1} in December. February results ranged between 170 to 260 mg L^{-1} .

In 2008, mean COD values for August were in the range 213 mg L^{-1} to 357 mg L^{-1} . The lowest mean levels were recorded in February and November and highest in May and August. 2006 – 2007 saw COD ranging from below the MRV of 100 mg L^{-1} to 990 mg L^{-1} in February 2007.

All results for oxygen demand fell within the expected range for estuarine samples and are not cause for concern.

3.1.9 Total Suspended Solids (TSS)

TSS values across all sites from October 2006 to November 2011 ranged between $<3 \text{ mg L}^{-1}$ and 195 mg L^{-1} . From June 2009 to November 2011, the highest values were always found near the seabed or in shallow areas (less than 5m depth), which indicates a high level of sediment re-suspension. The maximum value reported during this period was 95.9 mg L^{-1} , measured in the vicinity of the Cooling Water (CW) outfall when various works were in progress in the area.

In 2011, TSS values varied from $<3 \text{ mg L}^{-1}$ (several WQ sites in August) to 90.5 mg L^{-1} (site WQ02, at 6 m depth) in February. The average value for February was 29.3 mg L^{-1} , considerably higher than the rest of the 2011 surveys (which ranged from 3.4 mg L^{-1} to 12.7 mg L^{-1}). High values reported in February might have been a consequence of a combination of heavy rainfall prior to the survey and ongoing dredging activity, increasing the sediment suspended inputs from the catchments as well as the re-suspension of seabed sediments at periods of lower water.

In the 2010 surveys, TSS varied from $<3 \text{ mg L}^{-1}$ in February and May to 95.9 mg L^{-1} in November. The highest value is suspected to be a consequence of both works in progress around the CW outfall at the time of sampling and poor weather conditions.

⁴ The MRV was set at a lower level in February because of the level of dilution needed. According to the laboratory, the COD analysis method states that the method is valid for chloride values up to 1000 mg L^{-1} . Therefore to reduce the interference effect, samples were diluted. The dilution factor used was then incorporated in reporting the MRV.

TSS varied in 2009 from 3.9 mg L⁻¹ recorded at the surface in June to 50.9 mg L⁻¹ recorded near the seabed in December. The highest values were found from samples taken near the sea bed, indicating re-suspension of seabed sediments by tidal currents.

Between October 2006 and January 2009 TSS values displayed a large variation ranging between 5 mg L⁻¹ and 195 mg L⁻¹. Higher values were typically recorded in February and May.

3.1.10 Common Seawater Anions and Cations

Concentrations of common seawater anions and cations were in all surveys within expected values for estuarine waters across all sampling locations. Fluoride is the only anion with an EQS (5 mg L⁻¹) and all concentrations reported were well below this value (<1.5 mg L⁻¹). The August 2011 survey saw magnesium incorporated to the list of determinands; concentrations were within the expected range.

3.1.11 Nutrients

Survey results from October 2006 - November 2011 showed relatively low levels of all nutrient concentrations, some below the MRV, and did not indicate nutrient enrichment. Higher concentrations of phosphate and nitrogen compounds have been normally reported in February and November.

3.1.12 Metals

Heavy metals are found throughout the marine environment both as a result of natural background levels and anthropogenic input.

All metals sampled in 2010 and 2011 were, except mercury in 2011, found to be below the relevant EQS where specified and some were below the MRV. Mercury concentrations were reported below the EQS⁵ in all samples except in November at WQ03 at surface where there was a concentration of 0.356 µg L⁻¹.

In February 2009 all metals sampled, with the exception of copper, were found to be below the relevant EQS where specified. Copper exceeded the relevant EQS of 5 µg L⁻¹ at all sites and depths sampled. Concentrations ranged from 7 µg L⁻¹ at surface level at WQ01 to 1.3 µg L⁻¹ at WQ02 at a depth of 15m, the mean recorded value was 9.02 µg L⁻¹.

All metals concentrations sampled from June to December 2009, with the exception of nickel, were all below the relevant EQS concentration. In the June survey, nickel was found in concentrations greater than the EQS (30 µg L⁻¹) at sites WQ02, WQ03, WQ05, WQ07 and WQ10 in surface samples and site WQ01 at surface and at a depth of 12m. The maximum concentration recorded was 49.2 µg L⁻¹ at the surface at WQ05.

Concentrations of copper in 2008 exceeded its EQS of 5 µg L⁻¹ in all months at all

⁵ According with the directions given to the Environment Agency in connection with the Water Framework Directive (2000/60/EC) and Priority Substance Directive (2008/105/EC), The River Basin Districts Typology, Standards and Groundwater Threshold values (Water Framework Directive) (England and Wales) Directions 2010, from August 2010 mercury EQSs should be calculated from biota samples, with an EQS = 20 µg Kg⁻¹ (wet weight basis) Nonetheless, regulatory bodies in England and Wales still use the EQS based on water samples (0.05 µg L⁻¹) to evaluate areas with poor or non-existent baseline data.

sampling locations, with the exception of August. With the exception of February, arsenic was below its EQS of $25 \mu\text{g L}^{-1}$ for all samples. In February, the mean arsenic concentration was $40 \mu\text{g L}^{-1}$ with concentrations ranging between 34 and $45 \mu\text{g L}^{-1}$ and marginally above the EQS.

Copper was the only metal exceeding the EQS in February and May 2007 surveys, with concentrations ranging between 10 and $27 \mu\text{g L}^{-1}$ in February and between 7 and $9 \mu\text{g L}^{-1}$ in May. Arsenic exceeded EQS in February 2007, with concentrations ranging between 25 and $42 \mu\text{g L}^{-1}$. No metals exceeded their relevant EQS in August 2007.

3.1.13 Polychlorinated Biphenyls (PCBs)

Polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) were determined by solvent extraction followed by gas chromatography - mass spectroscopy (GC-MS). Phenols were determined by solvent extraction, derivitisation, followed by GC-MS. All results for total petroleum hydrocarbons (TPH) C5 to C44 for the 2011 surveys were reported as below the MRV of 0.2 mg L^{-1} .

PCB results for 2006 - 2011 have consistently been reported as below the MRV for all samples. Exceptions being:

- May 2010 where concentrations of all PCB congeners at all sampling sites and depths were below the laboratory MRV, except for congener 180, which showed concentrations slightly higher than the MRV at sites WQ01 (18m depth) and WQ02 (surface and 4m depth); and
- May 2007 PCB concentrations were below the MRV, with the exception of one sample at site WQ02 (9m depth), where values of 0.0085 mg L^{-1} were measured.

3.1.14 Polycyclic Aromatic Hydrocarbons (PAHs)

The majority of PAHs concentrations sampled between 2006 and 2011 were reported below MRV for all substances analysed in all samples; exceptions are detailed below. All but one sample (naphthalene, February 2010) were below the corresponding EQS.

- In June 2011 naphthalene was found in concentrations slightly higher than the MRV in three samples. The concentrations measured were much lower than the relevant EQS;
- In February 2010 concentrations of 12 of the 18 PAHs measured were below the laboratory MRV. The remaining six PAHs compounds were marginally over the MRV but of low concentration and lower than the EQS. One exception was naphthalene which was reported at a concentration of $1.31 \mu\text{g L}^{-1}$ at site WQ09 at surface which is higher than the relevant EQS;
- In June 2009 concentrations of 11 of the 18 PAHs measured were below the laboratory MRV. The remaining seven PAH compounds were marginally over the MRV but of low concentration. In August 2009 concentrations of 15 of the 18 PAHs measured were below the laboratory MRV at all sites. The remaining three PAH compounds were marginally over the MRV but of low concentration and at concentrations below the EQS;

- In August 2008 low levels of PAH were recorded at WQ04 (4m depth). In November 2008 naphthalene was recorded slightly above the MRV at WQ02 (13m depth); and
- In October 2006 PAH concentrations were all below the MRV of 0.010 $\mu\text{g L}^{-1}$ with the exception of fluoranthene and pyrene at WQ02 (9m depth), which were slightly above the MRV.

3.1.15 Phenols

From October 2006 to November 2011, Phenol has been detected regularly in most samples. Generally, most of the phenolic compounds measured were reported below or marginally above MRV and in concentrations below their relevant EQS.

3.1.16 Cyanide

Cyanide concentrations have consistently been below the laboratory MRV in all samples collected and analysed throughout 2009 - 2011. Laboratory MRV was 0.005 mg L^{-1} from June 2009 to November 2011 and from 2006 to February 2009 was 0.02 mg L^{-1} . Change in laboratory MRV denotes a change in laboratory used.

Cyanide concentrations reported for the sampling period from October 2006 – November 2008 were below the laboratory MRV for the majority of the samples, with none exceeding the EQS set at 1 mg L^{-1} .

3.2 Bathymetric Surveys

Dredging was undertaken at the site of the CW intake and outfall areas. Dredging at the CW outfall reinstated the outfall channel and portal openings, and at the CW intake reinstated the intake approach channel and permitted delivery of heavy / abnormal loads to the jetty adjacent to the intake. This was the first major dredging campaign carried out at the power station since the former oil station was decommissioned in the 1990s. Dredging commenced in the approach channel at the CW intake on the 28th January 2010 with the required levels achieved by the 11th April 2010. Dredging work commenced at the CW outfall site on the 9th October 2010 and was completed on the 21st October 2010. Dredging re-commenced in the approach channel with the required levels being achieved on the 22nd March 2011.

Figures showing bathymetric surveys, dates of which are outlined in table 1, are presented in Appendix 2.

3.2.1.1 Turbidity Monitoring

This comprised the taking of turbidity profiles and if necessary, to calibrate the turbidity sensor readings, water samples at specified times during dredging. During the intake and the outfall dredging works, turbidity profiles were taken as follows:

- On the spring flood tide;
- On the spring ebb tide;
- On the neap flood tide; and
- On the neap ebb tide.

In all cases, profiles were taken while dredging work was in progress:

- 100m upstream of the dredger;

- 100m and 500m downstream of the dredger;
- A background location unaffected by the dredging activity, normally 200-500m, at right angles to the current, away from dredging activity.

The first set of turbidity readings were taken on the 9th February 2010 with monitoring continuing on a weekly basis for approximately eight weeks until the first phase of dredging was complete.

The results of the turbidity monitoring are presented in Appendix 3 with turbidity in mg L^{-1} plotted against water depth. It can be seen that the turbidity in general is very low, ranging from 10 mg L^{-1} to 30 mg L^{-1} above background turbidity levels. Turbidity readings did not on any occasion exceed 300 mg L^{-1} above background level. There were occasions when the background turbidity levels were higher than those encountered 100m / 500m from the dredger, and these can only be explained as being due to other external factors. There are occasions where the turbidity results are far greater than the average, for example:

- 2nd March 2010 – Ranging from 100 mg L^{-1} to 230 mg L^{-1} above background level. These readings were being taken across one of the highest ranges of tide in the year and may be due to a plume settling down from vessel propellers or bucket overspill a little earlier;
- 9th March 2010 – Ranging from 0 mg L^{-1} to 140 mg L^{-1} above background level. These higher levels may be due to the survey vessel's propellers; and
- 2nd April 2010 – Ranging from 20 mg L^{-1} to 170 mg L^{-1} above background level. This may be due to the influence of vessel propellers.

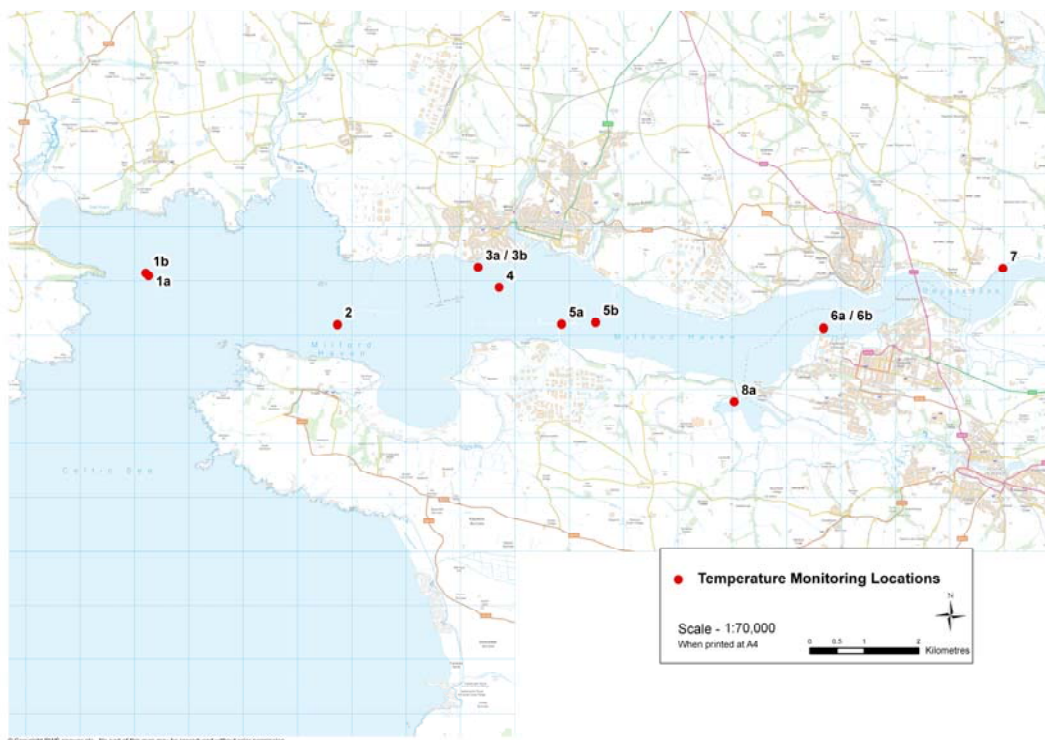
3.3 Automatic Haven Temperature Monitoring

During April 2011 a network of automatic water temperature loggers was established within Milford Haven. The network stretches from the Dakotian Buoy in the west to Rudders Boatyard in the east.

Twelve instruments are installed at seven locations for a minimum period of five years. The locations selected include those predicted to be subject to the thermal discharge plume (short-term field) and locations outside its direct influence, to give an indication of background water temperature within the Haven. Figure 2 shows the location of temperature loggers.

Locations are divided between near-seabed and near-surface monitoring with seven near-surface and five near-seabed loggers installed. Depth of loggers is 0.9 m below sea surface and 1m above sea bed. Salinity is measured by six instruments at three locations and temperature is measured at all locations. The surface temperature sensor located at 3b was in mid-April 2012 moved to Crow Pool, Pembroke River. The sensor was moved so it is more exposed to tidal movement. This network is supplemented by meteorological and tidal gauge data from Milford Haven Port Authority (MHPA) and data from the power station cooling water intake system when operational.

Figure 2: Temperature monitoring network throughout the Haven.



The following section presents a high level discussion of temperature and salinity measurements taken at all monitoring sites between 15th April 2011 and 31st December 2011. A more in-depth discussion on temperature and salinity data from this period is presented in Appendix 4 where the following quarterly reports are presented:

- April – June 2011;
- July – Sept 2011; and
- October – December 2011

For temperature reporting purposes the Haven has been split into three areas based on the location of the temperature loggers. This is presented in Table 7 below, which also shows the MHPA meteorological station closest to the sites.

Table 7: Haven areas and location of temperature loggers.

Monitoring Location	Area of Milford Haven	Monitoring Location	Meteorological Station (MHPA)
Dale - South Hook Reach	Lower Haven	1a, 1b and 2a	Milford Docks
Popton - Chevron Reach	Middle Haven	3a, 3b, 4a, 5a and 5b	Pembroke Dock
Pembroke Dock - Burton Reach	Upper Haven	6a, 6b, 7a and 7b	Lawrenny Yacht Club

3.3.1 April – June 2011

This quarter reported temperature monitoring from the 15th April to 30th June 2011 and represented the first three months of automatic temperature monitoring in the Haven. During this period Pembroke Power Station was not operational and no heated cooling water was discharged into Milford Haven. The main conclusions were:

- All sites in the Milford Haven Estuary showed a steady background increase in surface temperature from April to June 2011. Temperatures increased from 9°C to 16°C in the lower and middle estuary (sites 3a and 5a). The upper estuary showed an increase in surface temperature from 11°C in April to 18°C at the end of June 2011.
- Near bed temperatures were on average 1°C lower than the near surface values at all sites.
- The water temperature exhibited diurnal variation in response to the lunar tidal cycle in April and May 2011, with temperature at each surface site varying over the spring and neap tidal range by approximately 1.5°C. The highest and lowest daily averaged temperatures in each lunar tidal cycle occurred at maximum neaps and maximum springs respectively.
- All the surface and near bed sites apart from sites 3a and 3b showed that water temperature was closely correlated with the mixed semi diurnal tidal signature. Temperature was at a maximum at low water and a minimum at high water at sites 1a, 2a, 5a, 6a and 7a, but opposite at 4a with the maximum and minimum temperatures occurring at high water and low water respectively. The tidal signature was strongest in the upper estuary and weakest in the lower estuary.
- Surface and near-bed temperature at sites 3a and 3b showed temperature increased during daylight hours between 06:00 and 19:00 and decreased during the period 19:00 to 06:00 indicating diurnal variability in response to solar warming.
- There was spatial variation in surface and near bed water temperatures over the deployment period, with the highest temperatures being consistently recorded in the upper reaches of the estuary and the lowest temperature being recorded near the mouth of the estuary.
- The salinity measurements at the surface showed that average salinity was greatest in the mouth of the estuary with a consistent value of 33.66PSU, reducing to 32.15PSU in the middle part of the estuary and fluctuating between 28PSU and 32PSU in the upper reaches of Milford Haven.
- There was a weak response in the diurnal variability in salinity to the lunar spring/neap tidal cycle at site 7a in April and May 2011 with salinity varying by 1PSU from spring to neap. The highest and lowest average salinity in each lunar tidal cycle occurred at maximum springs and maximum neaps respectively and was opposite to the daily temperature variations where the highest and lowest average temperature in each lunar tidal cycle occurred at maximum neaps and maximum springs respectively.
- Overall, the mean salinity reduced over the June period at all three near-bed sites, with the most pronounced reduction at site 5b being measured around 20th June 2011. There was also a marked reduction in near-bed salinity at

site 7b towards the end of the deployment, reducing from a mean value of 31PSU to 22PSU over a two day period, and then increasing again to a mean value of 31PSU.

- The overall reduction in the background mean value at each near bed site and at the surface site 5A could be attributed to the increase in rainfall over the June 2011 period.
- The tidal signal in the salinity time series was pronounced in the upper reaches of the Haven and less pronounced towards the mouth. Where the tidal signature was pronounced, the salinity varied in magnitude depending on the state of the tide. At the start of springs, maximum and minimum salinity occurred at predicted mid-ebb and mid-flood respectively (predicted tides at Milford). Towards the end of springs and over the neap tidal period, maximum and minimum salinity occurred at predicted low water and high water respectively.
- The salinity time series for the surface and seabed at sites 5a and 5b exhibited typical estuarine behaviour, with the surface layer being less saline than the near-bed salinity time series by between 1PSU and 3PSU.
- The June 2011 salinity time series at sites 1a and 1b revealed that the surface salinity remained around a mean salinity of 33.5PSU, but the near-bed salinity time series showed a marked reduction in salinity from 34.5PSU at the start of June reducing to 31.2PSU at the end of June. From 12th June to the end of the first quarter period, the near bed salinity was less saline than the surface waters. Possible bio-fouling of the near-bed instrument may have affected the salinity reading at site 1b, although the near-bed salinities at all three near-bed sites showed a background drop in salinity over the June 2011 period. The salinity time series in the upper reaches of the Haven at sites 7a and 7b showed the salinity in the surface layer to be higher on average over the period of data overlap by 1PSU.

3.3.2 July – September 2011

During this period, the Pembroke Power station was not operational and no heated cooling water was discharged into Milford Haven. The second quarterly report discussed temperature and salinity measurements taken from 1st July 2011 to 30th September 2011, the main conclusions were:

- In July and August 2011, there was a defined spatial temperature gradient within Milford Haven. The highest daily averaged temperatures being measured in the upper reaches of the estuary and the lowest daily averaged temperatures being recorded near the mouth.
- In July 2011 the daily averaged temperature ranged between 15.59°C and 17.14°C and in August 2011, the daily average temperature increased slightly in the lower and middle Haven by 0.39°C, but remained stable in the upper Haven at 17.14°C. The spatial temperature variation throughout the Haven over September 2011 reduced by 1.55°C in the upper Haven to 15.6°C and in the middle part of the Haven by 1.2°C to 15.45°C. There was less change in water temperature in the lower Haven with a slight reduction in temperature of 0.69°C to 15.27°C. Notably, the temperature difference from the mouth to

the upper reaches of Milford Haven in July and August was 1.55°C and in September reduced to 0.33°C.

- There was a noticeable drop in surface temperature (0.3°C below other sites) at site 7a around the 21st September 2011. This drop in temperature also coincided with a drop in salinity of 4PSU over the same period. It is not obvious what caused the drop in salinity and temperature at site 7a. The daily averaged water temperatures at all sites appeared to vary in phase with the air temperature fluctuations measured at Lawrenny, increasing and decreasing in water temperature in response to an increase and decrease in the air temperatures.
- There was short-term temperature variability in response to the tidal cycle. There was a distinct relationship with surface temperature and the semi-diurnal tidal signature at all sites apart from site 3a where maximum temperatures occurred two to three hours after low water and minimum temperature occurred within one hour after high water. Mid-way through September, there was a phase shift with minimum temperatures being recorded at low water and maximum temperatures being recorded at high water. Notably at this time, the land was cooler than the sea as opposed to the summer months when the land is generally warmer than the sea water.
- There was no direct influence of rainfall events on the temperature of the water at the monitoring locations in Milford Haven at any time in this period.

3.3.3 October – December 2011

The Pembroke Power Station Environmental Permit was granted in November 2011 and this monitoring period saw power station commissioning commence. From 28th November and for most of December 2011 some heated cooling water was discharged into the Milford Haven waterway. The volume flux and temperature rises through the plant varied in line with commissioning requirements constituting a thermal load to the Haven which was small compared with that permitted. The main observations from this period are as follows:

- There was an overall decrease in mean water temperature throughout the Milford Haven waterway from October to December 2011, reducing from 14.47°C to 11.3°C at the seaward end of the Haven. In the upper reaches, the water temperature reduced from 14.37°C to 8.91°C between October and December respectively.
- There was a distinct change to the spatial temperature behaviour in the Haven from the 21st October onwards. The water temperature switched from progressively increasing longitudinally inland from site 1 to site 7, to progressively decreasing longitudinally inland; the seabed temperature near the mouth of the Haven at site 1b maintained the highest temperature for the deployment period after 21st October 2011. Surface temperature along the Haven decreased inland by approximately 0.35°C in November 2011 with temperature decreasing from a maximum of 13.94°C in the Dale-South Hook (D-SH) area to a maximum temperature of 13.59°C in the Pembroke Dock-Burton Reach Area (PD-B). In December 2011 the spatial temperature varied by 1.17°C along the Haven with surface temperature decreasing from a

maximum of 12.72°C in the D-SH area to a temperature of 11.3°C in the PD-B reach area.

- The daily averaged water temperature for all sites showed a relationship to the daily average air temperatures. An increase or decrease in air temperature corresponded to an increase or decrease in the daily averaged water temperature. Generally, the response of the water temperature to the change in air temperature was not instantaneous and lagged behind the change in air temperature by approximately two days.
- The water temperature responded in the short term to the semi-diurnal tidal cycle. In the Lower Haven, the water temperature rose abruptly, remained stable, and then fell abruptly at mid-flood and mid-ebb respectively for the deployment period. In the middle and upper areas of the Haven, the water temperature increased during flood and decreased over ebb tides, with peak and minimum temperatures being recorded close to high water and low water respectively. Temperature variation at the upstream sites between high water and low water was 1°C in November 2011 and 2°C in December 2012.
- Short-term temperature reductions were measured at sites 6a and 6b and occurred predominantly over the flood period. It may be that the temperature reductions were caused by water flowing over colder mud on the flood tide.
- The predominant wind direction in the Haven was from the west and southwest. Spatial variation in Haven water temperature showed a progressive increase upstream for the first three weeks of October before showing a progressive decrease upstream for the remainder of the deployment. When the wind direction came from the north, there was a distinct change to the spatial temperature pattern near the seabed with the upstream sites at sites 3b and 5b increasing to the same temperature as the seaward end of the Haven.

3.4 Intertidal and subtidal Fisheries (including invertebrates)

Fish and invertebrate surveys began in October 2006 to provide data to assist in determining baseline biological information. These have continued each year on a quarterly basis to date. The surveys have monitored fish populations within the Milford Haven waterway and Pennar Gut. Baseline surveys completed prior to 2009 highlighted seasonal population variation and for that reason quarterly trawl and seine net surveys have been continued. Seasonal baseline surveys of fish and invertebrate communities have comprised:

- Otter trawl surveys at 13 locations; and
- Seine net surveys at seven locations.

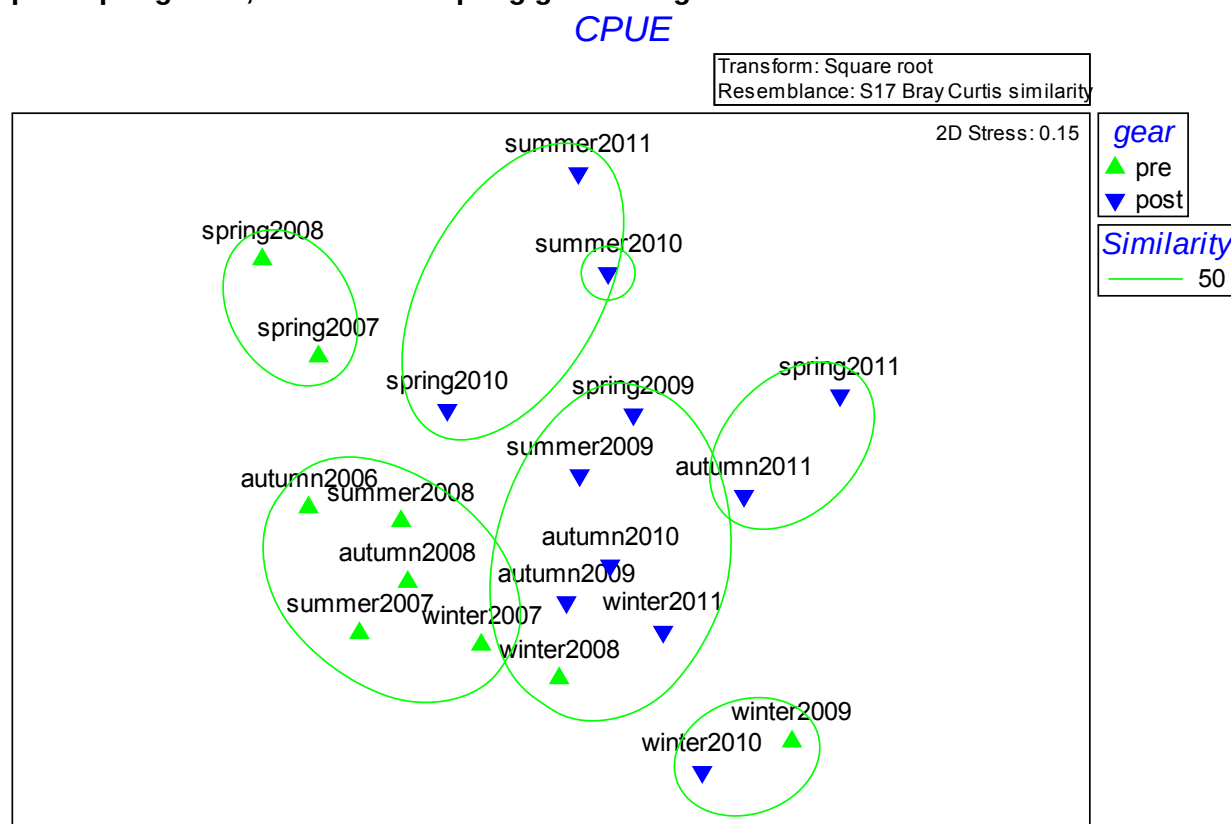
3.4.1 Change in Fishing Equipment

It should be noted that fishing equipment changed in spring 2009 to utilise techniques for sampling fish in transitional waters described in Water Framework methodologies, further detail on the different methodologies is included in the response to PO4a. Whilst both nets fished mainly demersal species, the main differences were that the otter trawl (a Water Framework Directive recognised sampling technique) targeted more individuals higher up in the water column and the seine net was longer, thus fishing a greater area of the intertidal zone. Consequently, the increased abundances

seen in 2009 to 2011 in the subtidal for species such as bass, whiting, cod (*Gadus morhua*) and pollack are most likely owed to an increased fishing efficiency, rather than a change in abundance or composition. Qualitative comparisons have been made where possible, and indicate that although the numbers of fish sampled (and to a lesser extent the number of species) has often differed between years, the species composition within the area of the Haven surveyed has remained stable throughout the study period.

In order to investigate the differences in the two data sets obtained before and after spring 2009 with the different otter trawl nets, an ANOSIM test was performed on data from all years and an MDS plot produced (Figure 3). The ANOSIM test indicated significant differences between samples collected pre- and post-spring 2009, when the sampling gear changed (ANOSIM, $R = 0.282$, $p < 0.05$). The resulting MDS plot supports this conclusion whereby the data from each sampling period or gear are generally separated into two halves with data from pre-spring 2009 (green symbols) clustered apart from those post-spring 2009 (blue symbols). However, slight overlap can be observed between the sampling periods where samples from winter 2008 and winter 2009 have clustered together with the post-spring 2009 samples mirroring the low R-value of the ANOSIM test.

Figure 3: Non-Metric Multidimensional Scaling (MDS) plot of all years / seasons fish community samples based on Catch Per Unit Effort (CPUE, fish per 100 m trawled) in Milford Haven. For clarity, sites have been pooled within each season. Green symbols represent samples pre-spring 2009 and blue symbols post-spring 2009, when the sampling gear changed



Results of the SIMPER analysis between pre- and post-spring 2009 samples showed that the differences observed were mainly due to the higher CPUE of sand smelt,

bass, herring and cods (cod, whiting, pollack, pouting) but lower CPUE of gobies, poor cod and dragonets since spring 2009 (Table 8). It can be concluded that the differences between samples collected with each sampling gear was due to differing CPUE of common species rather than wholesale changes in community composition.

Table 8: Results of the SIMPER analysis comparing average dissimilarity between pre-and post-spring 2009 samples. Top ten species are ranked in order of importance in driving dissimilarity between the gear groups

Pre- v Post-spring 2009 (average dissimilarity = 59.64)			
Species	Pre-Spring 2009 Average Abundance	Post-Spring 2009 Average Abundance	% Contribution to average dissimilarity
Sand smelt	0.65	0.78	10.54
Gobiidae	1.14	0.33	10.35
Poor cod	0.97	0.60	8.58
Bass	0.38	0.67	6.53
Herring	0.21	0.46	4.97
Whiting	0.34	0.44	4.56
Dragonet	0.57	0.27	3.88
Cod	0.05	0.36	3.33
Pollack	0.17	0.42	3.31
Pouting	0.11	0.33	3.22

In addition to the ANOSIM tests conducted on the sample composition data, the overall CPUE values (total catch as opposed to species composition) of each trawl in each year were tested for differences using the sampling gear change as a factor. A non-parametric Mann-Whitney test showed that significant differences in CPUE existed between the two types of otter trawl net used (pre-spring 2009, median = 0.96; post-spring 2009, median = 2.36) (Mann-Whitney, $U = 7024.5$, $p = 0.008$).

The ANOSIM and Mann-Whitney tests demonstrate that the two types of net catch similar species and compositions but the net used since spring 2009 catches significantly more fish. This greater catch efficiency can be useful as it can provide more data with respect to less abundant and incidental species.

Overall, the results above demonstrate the stable structure of the fish communities over the study period. However, owing to the quantitative differences between the sampling gears, any future quantitative comparisons for changes in individual species abundance should be made with care.

3.4.2 Species Patterns

Historic fish data from Milford Haven has been provided by the Field Studies Council (Crothers, 1966). Of the 80 taxa reported by Crothers, 28 have not been observed during the 2006 to 2011 monitoring. It should be noted that the 1966 list was not obtained by field work *per se* but from collection of records from a variety of sources including university and field centre research, observations and published literature. The absence of the 28 taxa can be explained by either their rarity or their specific habitat preferences. Additionally the Field Studies Council records come from the entire Pembrokeshire SAC, including offshore to the waters adjacent to Skomer. As a result some records are of species that would not be expected in the inner Haven

(e.g. basking shark, *Cetorhinus maximus* and tope, *Galeorhinus galeus*) whilst others are migratory species occurring in low numbers (twait shad, *Alosa fallax* and salmon). Certain species have specific habitat requirements and inhabit areas where trawling / seine netting is not feasible (e.g. many species of blenny, the conger eel, *Conger conger* and topknot, *Zeugopterus punctatus*). Some species documented in individual records are rare to Welsh coastal waters (e.g. sunfish, *Mola mola*) whilst others are species whose populations have dramatically declined across Europe over recent decades (angel shark, *Squatina squatina* and other species of ray and skate). The lack of these taxa in samples from 2006 onward does not necessarily indicate their absence.

The Environment Agency Wales (EAW) has been undertaking routine fish monitoring of Milford Haven for the Water Framework Directive since 2005. Between 2005 and 2010, EAW recorded 41 fish species. One of these, the giant goby (*Gobius cobitis*) has not been recorded in the current monitoring programme or historic records. The giant goby record may be erroneous given the very restricted distribution of this species in the south west of England. Solenette has been recorded as being present in the ichthyoplankton in 2011 (Young and Charalampopoulou, 2011). A third species, cuckoo wrasse (*Labrus mixta*), is recorded in Crothers (1966) but not in recent monitoring since 2006. This species has been found in EA monitoring every year since 2006 in seine nets adjacent to the NATO Jetty. As this species associates with fixed structures, it would not be expected to be present in the current monitoring programme.

3.4.3 Community Trends

Despite the minor differences in CPUE between corresponding seasons, no statistically significant differences were evident in subtidal fish data from 2009 to 2011. Any minor differences or fluctuations in both intertidal and subtidal populations are considered to be related to natural variability. Seasonal variability, driven by changing water temperatures is likely to play a significant role in the composition of intertidal and subtidal fish communities.

The lower temperatures experienced in the Haven during winter 2009/2010 may have affected some species; the abundance of species such as gobies and sand smelt was much lower in the intertidal zone during February 2010 compared with previous winters. Whilst it cannot be proven that the colder temperatures were responsible, it is possible that they forced fish to move to deeper waters.

The analysis of the community data suggests that there were no significant differences between the 2009, 2010 and 2011 data. Consequently, the data collected can be considered a suitable baseline against which any changes associated with the operation of the power station can be measured.

3.4.4 Invertebrate Taxa

Full lists of invertebrate taxa identified are provided in Appendix 5 and Appendix 6. The majority of taxa were epibenthic fauna, although occasional infaunal taxa were recorded. In all five years crustaceans and molluscs were the most diverse phyla recorded; these taxa dominated the composition of invertebrates in the samples obtained. Invertebrate composition is similar in all survey years.

The sampling methodologies employed are not recognised as standard techniques

for epifaunal invertebrate fauna and the data collected can only be considered as qualitative. The invertebrate composition of Milford Haven is discussed in more depth in the Pembroke 2011 Intertidal and Subtidal Ecology Reports (Nikitik, 2011a, 2011b).

3.5 Intertidal Ecology

The key objective of the intertidal ecology surveys was to inform on the natural variability of the ecological baseline conditions. Survey methodologies changed in some respects in 2009, for example timed searches were used rather than the random quadrat method. This change was made as the methodologies used before 2009 resulted in populations of certain organisms being represented as having intermittent populations when they are known to be ubiquitous in the area, also the methodologies did not accurately represent populations of organisms that undertake local migration. The methodologies used after 2009 followed MarClim protocols. As a result of this change in methodologies the data from 2009 onwards is not directly comparable with that from 2008 and before, any comparison needs to be undertaken with care.

The baseline surveys consisted of an annual mapping survey of intertidal biotopes at 11 sites on the mid and upper shore and five sites on the lower shore at increasing distances from the cooling water outfall. The rocky upper and middle shore zones are located between 900m to the east and 650m to the west of the cooling water channel. The lower shore locations are between 800m to the east and 500m to the west of the outfall. Surveys undertaken are:

- Species assemblage survey
- Trochid gastropods survey
- Barnacle survey
- Sublittoral fringe and shingle survey

Raw data from the intertidal surveys is provided in Appendix 7.

The intertidal environment of Pwllcrochan Flats was comprised of three major habitats. The upper shore was characterised by steep bedrock ridges backed by low cliffs while the mid shore areas were generally less steep and comprised of a variable mosaic of bedrock ridges, boulders, cobbles and gravel; the low shore was comprised of extensive flats of sandy mud with intermittent patches of shingle and shell.

Throughout the survey area the steep rocky infralittoral and upper shore areas were characterised by variable growths of lichens and brown algae respectively. The mid shore substrate was heterogeneous in character with sparse algal cover but a variable fauna with *Mytilus edulis* important at a number of sites. The low shore was comprised of sandy muds with a sparse epifaunal community.

There were two changes to biotope categories described in the 2006 survey within the area re-surveyed in 2008, both of which were associated with an increase in the invasive species *Crepidula fornicata* with one change also relating to a decrease in *Palmaria palmata* recorded. There were no changes to the biotopes assigned throughout the survey area between 2009 and 2011 compared to those previously reported in 2008.

In 2008 there were two minor changes to boundaries of biotope areas described in the 2006 survey associated with the extension of a spit of sediments and the other relating to biotope mapping of an area previously recorded as a subtidal channel. Neither of these changes are considered to reflect a significant change in the ecology of the area, but do indicate the potential variability of the sites in terms of natural physical habitat alternation (i.e. sediments shifting over time).

There was a significant change in the species assemblages from the 2006 to 2008 surveys in both the lower littoral habitats and the rocky shore habitats. This is attributed in part to the change in the species that were recorded within both habitats between survey periods and there was an increase in the variability of the species assemblages in the sites from each of the areas in the 2008 survey in comparison to 2006. There was also a general increase in species number across the sites within both habitats, supporting the observed change in community structure.

Between 2009 and 2011 distinct differences were evident between upper and mid shore rocky substrate communities, these followed typical, well understood patterns of zonation with distribution of flora and fauna being driven by natural environmental factors primarily related to tidal influences and level of exposure.

The rocky shore communities observed were considered as typical of the habitats sampled. The abundance of taxa ubiquitous to the upper and mid shore areas showed some variation between the five years' of data, although these changes were considered to be related to natural variability inherent in natural biological systems.

Between 2009 and 2011 some spatial variability in the abundance of the trochid gastropod *G. umbilicalis* was recorded across Pwllcrochan Flats, a similar pattern was also seen in the surveys in 2006 and 2008. This distribution pattern was considered to be related to natural environmental factors. Differences in mean width of *G. umbilicalis* between 2009 and 2011 are considered to be driven by natural population variability.

Between 2009 and 2011 the trochid gastropod *O. lineatus* was recorded at all rocky shore sites. Although some variability in numbers was evident, the population level was considered to be relatively consistent across Pwllcrochan Flats. Between 2009 and 2011 populations of *O. lineatus* were sampled by the timed search technique, results were not comparable to those reported for 2006 and 2008 where the random quadrat approach was employed. Random quadrat results from 2006 and 2008 found intermittent distribution of *O. lineatus* across Pwllcrochan Flats, whereas the timed search results show that this species is ubiquitous.

Between 2009 and 2011 total barnacle numbers varied appreciably across the survey area with no consistent pattern. Both *E. modestus* and *S. balanoides* were recorded throughout the study area, although *E. modestus* was consistently the more abundant taxon, reflecting historical patterns.

The epibiota recorded from the low shore mud habitats were considerably reduced between 2009 and 2011 compared to 2006 and 2008. It is considered that this may be related to natural transitory sedimentary patterns.

Sediment dwelling intertidal infauna was dominated by polychaetes and amphipods typical of the habitats sampled. The communities present were indicative of undisturbed conditions.

3.6 Ichthyoplankton

The larval and juvenile stages of most fish species are vulnerable to entrainment owing to their small size and poor swimming capability. This survey was designed to gather further baseline information on the identity and abundance of fish eggs and larvae present in the plankton close to the proposed cooling water intake.

The sampling protocol used is based on the methods used by Cartwright (1978), further detail on the sampling methodology can be found in our response to PO4a.

The year-round monthly ichthyoplankton surveys undertaken in 2006-7 (reported in the CES, 2007) showed that peak ichthyoplankton densities occurred in May to July, with minimal quantities of ichthyoplankton being present at other times of year. Therefore, when ichthyoplankton surveys were recommenced in 2009, they were undertaken in these three months only, similarly in 2010 and 2011.

Raw data from the ichthyoplankton surveys is provided in Appendix 8

Gobies dominated the samples in 2007, 2009, 2010 and 2011. Results from the 2007 ichthyoplankton surveys indicated that concentrations of larvae were generally lower in Pennar Gut than in the adjacent areas sampled in the main body of the Haven. In 2009, Pennar Gut had the highest number of individuals, when averaged across the ebb and flood tides. During 2010, Pennar Gut had the highest number of individuals during the months of June and July. However, in 2011 the highest concentration of larvae was found in East Pennar with Pennar Gut exhibiting the lowest concentration in June and July.

There is a stock of spring spawning herring in Milford Haven. Results from the previous years' sampling show that clupeid larvae started to appear in the samples in April. Numbers peaked in May and ceased to be present in any great abundance after August. No sampling was undertaken during May 2009; sampling carried out in May 2010 showed that peak herring densities occurred at East Pennar, and lowest at Pennar Gut however the reverse was observed during May 2011.

Overall densities of herring are highest during May compared to other months as this is the peak time after spawning. Spatial variability in herring densities are likely to be caused by proximity to spawning grounds and subsequent dispersion of populations. Variability in the timing of sampling in relation to tidal cycles is also likely to affect the abundance of herring observed at different sites and tidal states.

Sand smelt and smooth sandeel were species new to the ichthyoplankton surveys in 2010 and were also observed in 2011. These species were, however, uncommon in the samples which likely relates to relative distance from spawning areas. Sand smelt numbers were increased in the 2011 ichthyoplankton samples compared to 2010. This species was also present earlier in the year, May and June 2011 compared to July only 2010. Brill was the only new species to the 2011 survey

Bass were present in the 2011 surveys after being absent since 2007 and solenette were also observed having been absent in 2010. These fluctuations are likely to reflect natural variation. Other flatfish such as plaice, flounder and Dover sole have maintained a persistent absence from the survey since 2007.

The numbers of larvae present per 10^6 m^3 water are much reduced when considered in terms of adult equivalents. Many fish species tend towards massive over-production of eggs and natural mortality in early life stages is very high. For example

the calculation of EAVs shows for May 2011, 27,000 herring larvae equated to only 122 adult equivalents per 10⁶ m³ of water.

Significant differences were observed between 2007 and 2009, however multi-dimensional scaling (detailed in the full report) show that 2010 results indicated no detectable consistent temporal shift. Results from 2011 confound these findings demonstrating little separation from 2010 and considerable overlap with 2007.

Other analysis techniques such as SIMPER and ANOSIM tests are also detailed in the full reports. The SIMPER results strongly suggest that the significant differences found from the ANOSIM tests are the result of differing abundances of common taxa (e.g. Gobiidae and Blennidae), rather than loss of specific taxa, or fundamental changes in the structure and composition of the community. These results suggest that ichthyoplankton community differences between years and between months are the result of natural variation in abundances.

The area of Milford Haven sampled supports a diverse community of ichthyoplankton species. The range of species present indicates that populations are typical of estuarine conditions and the area of Milford Haven sampled supports a diverse ichthyoplankton community. Natural variability in spawning location, intensity and subsequent dispersion are the likely cause of inter-annual differences in the spatial distribution and abundance of post-larval fish.

There was little difference in the dominant ichthyoplankton species between 2007 and 2011. Any differences between years and between months are the result of natural variation in abundances of the dominant species rather than changes caused by environmental stress.

3.7 Phytoplankton and zooplankton

Phytoplankton and zooplankton samples were collected in October 2006 at each ichthyoplankton monitoring site. Samples collected in June and July 2009 for ichthyoplankton monitoring were retained and have now been analysed for zooplankton for inclusion within the baseline data, the samples have degraded and no phytoplankton analysis is possible. Zooplankton results for these samples will be forwarded to the Environment Agency when they are available.

Raw data from the plankton surveys is provided in Appendix 9

During the 2006 survey a total of 33 species of phytoplankton were recorded as present, although an average of 21 different species was recorded within each sample. The samples contained an average of 119 individuals, dominated by diatoms, one of the most common types of phytoplankton.

The 2006 zooplankton assemblage was composed of calanoid copepods, harpacticoid copepods, mysid, cumacean, barnacle nauplius and crab (zoea). The assemblage was dominated by copepods and in particular by the sub order calanioda. Copepods are by far the most abundant element of the zooplankton.

3.8 Subtidal Benthic Ecology

A key objective of the subtidal benthic programme was to monitor the recovery of the benthic species community in the areas dredged. Initial work undertaken for the CES in July 2006 provided a pre-construction baseline, subsequent monitoring was

undertaken during late summer 2010 and 2011 so as to allow valid comparison with work previously undertaken for the CES.

Milford Haven is an industrialised waterway and as such any baseline information collected will not necessarily reflect a wholly natural system. With domestic and industrial sources discharging into the Haven sediments are known to be contaminated by a range of pollutants.

The survey in 2006 identified four sediment groups throughout the study area and multi-dimensional scaling (MDS) analysis showed the sites clustered best into seven different benthic community types.

These benthic communities were characterised by many species (rather than a few dominant species). There were also similarities in the species lists between the seven benthic groups suggesting gradual changes in the benthic community type across the study area. The benthic communities in the study area are dominated by infaunal polychaetes.

The surveys in 2010 and 2011 identified considerable spatial variability over the survey area in both the benthic communities and sediments, with natural environmental factors responsible for driving community structures and sediment distribution.

Levels of metals in all three surveys are considered elevated above background concentrations, although these levels are similar to those found in the wider waterway and at other locations in South Wales. Although metal levels were elevated above typical background levels, generally concentrations did not exceed the relevant Probable Effect Level (PEL) and most concentrations were below the relevant Threshold Effects Level (TEL). Consequently, it is considered that any biological effects from heavy metals are likely to be minor and chronic rather than acute.

The presence of PAHs in Milford Haven sediments in appreciable amounts is to be expected due to chronic inputs from petrochemical industrial discharges. However, compared to data produced by the National Marine Monitoring Programme between 1999 and 2001 which reported that maximum PAH levels in UK marine sediments exceeded 200,000 $\mu\text{g kg}^{-1}$ (MEMG, 2004) the concentrations reported here can be considered as moderate. Furthermore, the concentration ranges for individual PAHs observed were comparable with other major UK estuaries and are generally lower than heavily industrialised UK estuaries. As with metals, the level of PAHs in the sediments reported here were not elevated appreciably above the relevant TEL, consequently it is considered that any associated biological effects will be chronic rather than acute.

The results of the studies carried out in 2010 and 2011 showed no evidence to indicate any impact of dredging or other construction activities on the subtidal habitats or communities in the vicinity of Pembroke Power Station development. Subtidal benthic raw survey data is presented in Appendix 10.

3.9 Eels

Eel surveying is being discontinued at the request of the Environment Agency. Eels have been detected in low numbers in some of the fisheries trawls and specific fyke netting for eels was undertaken in 2011. This survey data is available if required but

is not included here and no further specific work for eels will be undertaken.

3.10 Eelgrass Surveys

Eelgrass surveys began in 2009 to provide data to assist in determining baseline. Surveys have continued each year, taking place in September or October in all years with an additional survey in May 2010. Eelgrass survey data is presented in Appendix 11.

Survey results from 2009 showed that the eelgrass beds in Pennar Gut were located primarily on the extensive mud flats on the south bank extending from the muds adjacent to the power station site in the west to Bentlass in the east. A smaller bed was also located on the north bank immediately upstream of Pennar Ridge. The major bed on the south bank was almost continuous throughout the upper and mid shore with coverage over the area only interrupted by drains and ditches, particularly Goldborough Pill. The small bed on the north bank was also an unbroken area of eelgrass. The area of coverage was generally characterised by consolidated muds with the seaward extent being marked by the shelving of the mudflats towards the channel of the Pembroke River where the substrate became more unstable. The eelgrass bed on the south bank of Pennar Gut extended to approximately 88ha, while the small bed on the north shore covered approximately 1.9ha.

In 2009 an eelgrass bed extended over the majority of the intertidal mudflats in Pennar Gut on the south shore of the Pembroke River with an area of approximately 88ha; a smaller area on the north shore covered approximately 1.9ha, the beds were comprised predominantly of *Zostera noltii* although some *Z. angustifolia* was also present. In 2010 and 2011 similar beds were identified with the main bed extending to 91ha and the smaller bed on the north shore covering 1.6ha. In 2011 eelgrass beds covered approximately 90ha and 1.7ha. In 2010 and 2011 only *Z. noltii* was identified.

In all years the beds were characterised by a narrow peripheral band of low density eelgrass growth with considerably greater density of eelgrass present throughout the majority of the bed. In 2009 the average eelgrass coverage was 75% while the figure was 68% and 76% in 2010 and 2011 respectively. Bed extent and shoot density was analogous with data collected by EAW.

The mean wet weight biomass of eelgrass was 13.7g per 0.01m² in 2009, 3.8g per 0.01m² in 2010 and 7.0g per 0.01m² in 2011. This reported variability was considered to be related to natural environmental factors. There was no evidence that macroalgae was encroaching on the eelgrass beds or impeding eelgrass growth.

Sediments throughout the eelgrass bed were comprised of sandy muds. Variation in levels of sediment-bound metals and organic compounds was evident between years although concentrations were generally within environmental guidelines. This variability was considered to be related to natural variability and the recorded contaminant levels were not considered to be influencing eelgrass or associated fauna including feeding birds and fish. In all years the water quality in the vicinity of Pennar Gut was considered to be good with low levels of contaminants.

The benthic communities associated with the eelgrass beds were relatively consistent between years with any variability related to natural environmental factors. In all years the communities were dominated by *Hydrobia ulvae*.

Following WFD protocols the eelgrass beds in 2010 and 2011 were classified as being of good ecological status.

3.11 Subtidal Epifauna Surveys

Baseline diving surveys were first undertaken in November 2011. More information is included here to supplement that contained in the submission in line with PO4a as survey analysis was incomplete at the time of submission. All surveys, except for a reference site which was located east of the CW outfall near the Cleddau Bridge, were undertaken in close proximity to the Power Station CW outfall channel in Milford Haven. The aim of the survey was to assess both the epibenthic habitats and the gradients in biodiversity with increasing distance from the CW outfall.

Four subtidal survey sites were established, the co-ordinates of the each survey site and dates the sites were surveyed are presented in Table 9 below. Due to weather conditions it was not possible to establish and survey a fifth site.

Table 9 presents a list of habitats that were recorded from the four sites with the numbers of species recorded at each site. Survey data is presented in Appendix 12.

Table 9: List of habitats and number of species recorded at each site

Site reference	NGR	Situation	Habitat description	No. of taxa
Ref_1	SM 97250 05073	West side of Cleddau Bridge, close to the north shore of the channel.	Lower circalittoral, tide-swept, heavily silted, vertical bedrock wall with sponges and tunicate turf.	123
PPO_1	SM 92966 03963	Southern edge of shipping channel, 100 m west of the outfall buoy.	Lower circalittoral, tide-swept, vertical to near vertical, bedrock wall dominated by <i>Antedon bifida</i> and encrusting sponges.	127
PPO_2	SM 92881 04041	Southern edge of shipping channel 200 m west of the outfall buoy and 100 m west of PPO_1.	Upper circalittoral, tide-swept, vertical, bedrock wall covered in <i>Antedon bifida</i> with sponge crusts and <i>Crepidula fornicata</i> .	117
PPO_3	SM 92745 04084	Southern edge of shipping channel 370 m west-northwest of the outfall buoy and 170 m north west of PPO_2.	Lower circalittoral, tide-swept, silted, small, vertical, bedrock wall dominated by sponge crusts and bryozoan turf.	82

A summary of each of the survey sites is presented below.

Survey Site Ref_1	
Physical parameters	Depth of survey site: 14.5m Below Chart Datum (BCD) / 18.2m below OD Tidal streams: Accelerated Zone: Lower circalittoral Wave exposure: Very sheltered.
Habitat	Vertical, heavily silted bedrock wall from 10-23m BSL dominated by sponge (<i>Halichondria panicea</i> , <i>Amphilectus fucorum</i> , <i>Halichondria bowerbankii</i> , <i>Haliclona occulata</i> , "lophonopsis" with turf beneath dominated by tunicates (<i>Dendrodoa grossularia</i> , <i>Polycarpa</i> sp.) and scattered Didemnids. Very sparse hydroids and branching bryozoa.
Reason for selection	Similar habitats to the PPO sites. Long slack window (up to 3 hours on a neap tide) which greatly increases the available working time on site.
 	
<i>Tubularia indivisa</i> , <i>Amphilectus fucorum</i> and <i>Dysidea fragilis</i> . <i>Halichondria panicea</i> and juvenile <i>Antedon bifida</i> .	

Survey Site PPO_1	
Physical parameters	Depth of survey site: ~9.6 – 11.5m BCD / 13.3 – 15.2m below OD. Zone: Lower circalittoral Tidal streams: Moderately strong Wave exposure: Very sheltered
Habitat	Vertical to near-vertical bedrock wall approx. 5-6m long and 2m high. Dominated by <i>Antedon bifida</i> and numerous encrusting sponge species. Also occasional branching sponge species.
Reason for non-selection	Suitable height, width and angle of wall to allow hanging of quadrats.

	
Quadrat cells dominated by <i>Antedon bifida</i>	<i>Halichondria panicea</i>, sponge crusts and hydroid / bryozoan turf

Survey Site PPO_2	
Physical parameters	Depth of survey site: 10.0 – 11.5m BCD / 13.71m – 15.21m below OD Tidal streams: Accelerated Zone: Upper circalittoral Wave exposure: Sheltered
Habitat	Vertical bedrock wall ~1.5m high. Wall mainly covered in <i>Antedon bifida</i> with numerous sponge crusts and <i>Crepidula fornicata</i>. Occasional/rare branching sponges, anemones and bryozoans.
Reason for selection	Suitable height, width and angle of wall to allow hanging of quadrats.
 <i>Urticina</i> sp.	 <i>Antedon bifida</i> and <i>Sagartia elegans</i>

Survey Site PPO_3	
Physical parameters	Depth of survey site: 9m BCD / 12.7m below OD Tidal streams: Accelerated Zone: Lower circalittoral Wave exposure: Sheltered
Habitat	Silted bedrock reef with small vertical wall approx 5 m long and 1m high (1.5 m in places). Fissures and crevices along wall with lots of weathered fragments of rock (pebble

	sized). Moderately sparse fauna, dominated by sponge crusts, <i>Sabellaria spinulosa</i> and bryozoan turf. Rock outcrop/vertical sloping into pebbly mud with <i>Crepidula fornicata</i> .
Reason for selection	Suitable height, width and angle of wall to allow hanging of quadrats.
	
<i>Necora puber</i> and <i>Flustra foliacea</i>	<i>Raspailia ramosa</i> , <i>Antedon bifida</i> and <i>Dysidea fragilis</i>

Each of the sites surveyed are typical of reef communities in this reach of Milford Haven and were in areas swept by strong tides. All sites can be considered to have the same biotope code; “cushion sponges, hydroids and ascidians on tide-swept, turbid, sheltered circalittoral rock” which accurately defines the general community structure at each site.

The native oyster, *O. edulis*, was the only Biodiversity Action Plan species recorded at sites Ref_1 and PPO_2. The non-native Pacific oyster *Crassostrea gigas* was not recorded.

Subtle differences were recorded between those in proximity to the outfall and the reference site which may be attributable to the following:

- subtle differences in the tidal regime between locations;
- differing substrates between the reference site and the CW outfall sites. The outfall sites are comprised of low-lying vertical sandstone whilst the reference site is limestone and some metres above the seabed; and
- a softer substrate is likely be increasingly susceptible to scour and erosion perhaps preventing the establishment of larger sponges.

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