HORIZON NUCLEAR POWER

WYLFA NEWYDD

ENERGY WORKING FOR BRITAIN

Wylfa Newydd Project

6.4.83 ES Volume D - WNDA Development App D13-1 - Water Quality and Plankton Surveys Report

PINS Reference Number: EN010007

Application Reference Number: 6.4.83

June 2018

Revision 1.0

Regulation Number: 5(2)(a)

Planning Act 2008
Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

Horizon Internal DCRM Number: WN0902-JAC-PAC-APP-00164

[This page is intentionally blank]

Wylfa Newydd Project

Horizon Nuclear Power Ltd.

Water Quality and Plankton Survey Report

60PO8007/AQE/REP/004 | 4

January 2018

WN03.01.01-S5-PAC-REP-00022

Document history and status

Revision	Date	Description	By	Review	Approved
1	February 2015	Water Quality and Plankton Survey Report	Victor Guerra, Anastasia Charalampopoulou and Karen Watts	Colin Trigg	Rob Bromley
2	March 2016	Water Quality under Non-operational Conditions section added	Victor Guerra	Matt Robson	Rob Bromley
3	May 2017	Water Quality in Holyhead Deep area	Victor Guerra	Rob Bromley	Rob Bromley
4	January 2018	Water Quality in Cemlyn Lagoon and Coastal areas added.	Victor Guerra	Anastsia Charalampopoulou	Rob Bromley

Distribution of copies

Revision	Issue approved	Date issued	Issued to	Comments

Wylfa Newydd Project

Project No:	60PO8032
Document Title:	Water Quality and Plankton Survey Report
Document No.:	60PO8007/AQE/REP/004
Revision:	4
Date:	January 2018
Client Name:	Horizon Nuclear Power Ltd.
Client No:	WN03.01.01-S5-PAC-REP-00022
Project Manager:	Rob Bromley
Author:	V. Guerra, A. Charalampopoulou, K. Watts.
File Name:	Water Quality and Plankton Survey Report

Jacobs U.K. Limited

Kenneth Dibben House
Enterprise Road, Southampton Science Park
Chilworth, Southampton SO16 7NS
United Kingdom
T +44 (0)23 8011 1250
F +44 (0)23 8011 1251
www.jacobs.com

Contents

Executive Summary

Jacobs UK Limited (Jacobs) was commissioned by Horizon Nuclear Power Wylfa Limited (Horizon) to undertake a full marine survey programme to inform various applications, assessments and permits to be submitted for approval to construct and operate the Wylfa Newydd Generating Station and Associated Development.

Baseline water quality and plankton surveys have been carried out with the aim of characterising the prevailing environmental conditions and to enable assessment of the predicted effects of the Wylfa Newydd Generating Station and Associated Developments e.g. Cooling Water (CW) intake and Marine Off-Loading Facility (MOLF), within the final Environmental Statement and associated applications. This report details the findings of the water quality and plankton surveys that were carried out during the baseline period (between May 2010 and November 2014) and two additional water quality surveys carried out in December 2015 and February 2016 within the same area. In addition, the report also presents the findings of a single water quality survey carried out within the licensed disposal site Holyhead North (IS043).

Water Quality

Physico-chemical data recorded between May 2010 and November 2014 showed no evidence of a permanent thermocline, halocline or seasonal stratification of the water body along the north Anglesey coastline, and were consistent with a fully mixed marine water body. Weak thermal stratification was occasionally recorded at some sites and signs of a thermal influence (probably the existing cooling water discharge plume) were occasionally observed at sites WQ2, WQ6 and WQ7. Water temperatures recorded during the baseline monitoring programme are comparable and within the same range to the long-term temperature records for the area held by The Centre for Environment, Fisheries and Aquaculture Science (Cefas). Dissolved oxygen data recorded each month indicate high dissolved oxygen standards according to the Water Framework Directive (WFD) classification.

Chemical analysis results were reported at concentrations typical of coastal waters and in line with previous studies carried out around the north of Anglesey. Many concentrations were consistently reported as below the Minimum Reportable Value (MRV) or below the Limits of Detection (LoD). Concentrations reported above any of these values were compared with their Environmental Quality Standard (EQS) when applicable. After comparison with the relevant EQS, all data collected to date indicate good chemical status based on the specific pollutants, priority substances and other pollutants covered under the WFD and Priority Substance Directive between May 2010 and November 2014. Total suspended solids data indicate clear/intermediate turbid water. Nutrient concentrations were low and consistent throughout the monitoring programme, indicating very little nutrient enrichment in the survey area. Average concentrations of dissolved inorganic nitrogen (DIN) indicate high DIN standard under the WFD classification in 2010-11 and 2011-12. Due to limited DIN data availability for the winter months after 2012, no classification was inferred after 2011-12. Most metals analysed were reported at low levels, with some below the MRV. Mercury exceeded the short-term EQS or maximum allowable concentration (MAC-EQS) on one occasion in Oct 2010. Most of the organic compounds monitored were consistently found below or marginally above the MRV. All compounds were found well below their relevant EQS.

β radiation levels detected in some samples were comparable to the Radioactivity in Food and the Environment (RIFE) data for the region. High levels of radiation were reported in samples taken in November 2010 and February 2012, which is possibly attributable to historic Sellafield contamination of the Irish Sea (Cefas, 2011 and 2012).

In response to the planned shutdown of the remaining reactor at the Existing Power Station on 30 December 2015, two additional surveys were carried out in December 2015 to validate the baseline data and again in February 2016 to inform non-operational conditions. Physico-chemical data and chemical results reported by the laboratory were in line with the data reported during the baseline monitoring programme. As no discernible differences were observed between the data reported for the baseline period and during non-operational conditions, it is considered that the Existing Power Station was having a minor/undetectable impact on water quality in the adjacent water body during operation.

On 31 October 2016, an additional water quality survey was carried out within the licensed disposal site Holyhead North (IS043), the area identified as the most suitable disposal site to receive the dredged material from the Wylfa Newydd Associated Development. Physico-chemical and chemical results reported indicate a good chemical status with many concentrations reported below the MRV.

Phytoplankton

Overall, there was little difference in phytoplankton abundance and community composition between tidal states and monitoring sites along the north Anglesey coast. As expected, changes in phytoplankton abundance and community composition were driven by seasonal nutrient and light availability, the timing of the peak in phytoplankton abundance being dependent on light and mixing conditions. Diatoms tended to numerically dominate the spring phytoplankton peak in abundance, although the prymnesiophyte, *Phaeocystis globosa*, was the most abundant species in May 2010, whilst microflagellates reached very high abundances in April 2012, prior to the diatom increase in May 2012. Phytoplankton production was relatively low, most likely as a result of the low nutrient levels, a known feature of this area of the Irish Sea. The phytoplankton community composition off north Anglesey is considered usual for this part of the Irish Sea. No bloom densities were reached, according to WFD classification, throughout the monitoring programme and any harmful/toxic algae present were recorded at very low densities and have largely been reported from the Irish Sea since the 1950s.

Zooplankton

Results showed no significant differences in zooplankton community composition and abundance between tidal states and between the different sites sampled along the north Anglesey coast. Differences identified in the zooplankton analysis between months indicated that the zooplankton community is driven predominantly by the varying environmental factors that constitute changes in season as well as the timing of the spring phytoplankton peaks. Copepoda, which are known to be an important food source for the larval stages of many commercial fish species in the Irish Sea, dominated the zooplankton community.

Overall, the water quality and plankton data are in line with previous studies of the waters off the north coast of Anglesey, and as such provide an adequate baseline against which predicted effects of the development can be assessed.

1. Introduction

1.1 Overview

Horizon Nuclear Power Wylfa Limited (Horizon) is planning to develop a new nuclear power station on Anglesey as identified in the *National Policy Statement for Nuclear Power Generation (EN-6)* (Department of Energy and Climate Change, 2011). 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 addition to the ecological survey programme carried out by Jacobs, oceanographic characterization was also undertaken by Titan Enviromental Surveys Ltd. The finding of the oceanographic characterization is reported separately in Titan (2012).

This report details the findings of the water quality and plankton survey programme carried out between 2010 and 2016 around the north Anglesey coast, within the vicinity of 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). In addition, the report also presents the findings of a single water quality survey carried out in October 2016 within the licensed disposal site Holyhead North (IS043).

This report uses a number of technical terms and abbreviations. Key terms are capitalised and explained with their acronyms within the text. References to legislation are to that legislation as in force at the time of the publication of this report.

1.2 The Wylfa Newydd Project

The Wylfa Newydd Project includes the Wylfa Newydd Generating Station and Associated Development. The Wylfa Newydd Generating 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 will include steam turbines, control and service buildings, operational plant, radioactive waste storage buildings, ancillary structures, offices and coastal developments. The coastal developments will include a Cooling Water System (CWS), two breakwaters, and a Marine Off-Loading Facility (MOLF). A Disposal Site for dredged material would also be required and the proposed location for this is at Holyhead North disposal site, approximately 15km from Holyhead Harbour.

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. It is bounded to the north by the coast and the existing Magnox power station (the Existing Power Station). To the east, it is separated from Cemaes by a narrow corridor of agricultural land. The A5025 and residential properties define part of the south-east boundary, with a

[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 Workers' 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* (Department of Energy and Climate Change, 2011) as potentially suitable for the deployment of a new nuclear power station.

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].

1.4 Study Aims and Objectives

The aim of the water quality and plankton surveys was to determine the prevailing environmental conditions and collect baseline data to inform the various applications, assessments and permits required to construct and operate the Wylfa Newydd Generating Station.

The objective of the water quality and plankton monitoring programme was to characterise the following within the vicinity of the Wylfa Newydd Development Area:

- baseline water quality conditions;
- water quality when the Exisiting Power Station is non-operational; and
- baseline plankton (phytoplankton and zooplankton) data.

These data provides information on the physical, chemical and biological aspects of the water column as well as spatial and temporal variation of plankton throughout a tidal cycle and throughout the year.

As part of the Environmental Impact Assessment (EIA) and Habitats Regulations Assessment (HRA) the need for detailed knowledge of temporal and spatial data on the water quality and plankton has been identified. This report presents the findings of work carried out from May 2010 to November 2014.

1.5 Study Area

The tidal excursion along the north coast of Anglesey is between 20 km and 25 km to the south-west (ebb) and south-east (flood). It was not feasible to survey this entire area and therefore surveys were focused on a central study area where potential effects may occur. The extent of the central study area was defined by professional judgement and by the results of preliminary hydrodynamic modelling, which provided an initial indication of the dispersion of the cooling water (CW) discharge from the Wylfa Newydd Generating Station.

The extent of the study area relates to the near-, mid- and far-field zones which are defined by the dominant, physical mixing processes of the CW discharge with the ambient waters and are defined in *Cooling water options for the new generation of nuclear power stations in the UK* (Environment Agency (EA), (2010).

The near-field (NF) zone is determined by the initial momentum and buoyancy of the CW discharge from the Existing Power Station, the mid-field (MF) zone by dilution and turbulent mixing by tides and winds, and the far-field (FF) only by residual currents and weather conditions as buoyancy and temperature differences from ambient are negligible (EA, 2010). In reality, these zones are in a constant state of flux caused by prevailing tidal and weather conditions; however, a study area of 5 km radius from the Power Station was defined to incorporate the three zones. The study area was selected based on early Delft3D modelling of the Existing Power Station's CW discharge and its consequential plume dispersion. Revised Delft3D thermal and hydrodynamic modelling undertaken for the latest design of the Wylfa Newydd Generating Station has demonstrated the continued validity of the selected sites.

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

Reference (control) sites were selected outside the study area and/or tidal excursion where appropriate, to ensure sites were beyond the influence of the Existing Power Station. Data from reference sites have been used where appropriate to provide a comparison to sites within the zone of influence.

2. Baseline Data Collection

The baseline monitoring programme ran from May 2010 to November 2014. An additional survey was carried out in December 2015 to validate the baseline data and again in February 2016 to inform non-operational conditions. Findings of the latest two surveys are reported separately in Section 4. In addition, in October 2016 a single survey was carried out around the northwest of Holyhead as part of the characterisation of the marine environment around the proposed disposal site at Holyhead North (site code IS043). Findings of this survey are reported in Section 5.

The baseline water quality and plankton (zoo- and phytoplankton) surveys were initially carried out monthly from May 2010 (Table 2.1) to provide an understanding of temporal trends. The survey programme was reviewed on a regular basis, ensuring all requirements of the monitoring work were met. Following reviews of all the data gathered, changes to the programme were made (as detailed in each section) i.e. samples were collected over 12 months for the first two years of the monitoring programme (May 2010 to April 2012) with a reduction in sampling effort from May 2012 onwards (see Section 3.2.2).

Table 2.1 : Water quality and plankton baseline survey dates (from May 2010 to November 2014).

Survey Dates				
2010	**2011**	**2012**	**2013**	**2014**
-	23-Jan	11-Jan	-	-
-	16-Feb	26-Feb	19-Feb	19-Feb
-	15-Mar	21-Mar	19-Mar	26-Mar
-	12-Apr	02-May*	26-Apr	16-Apr
12-May	18-May	16-May	04-Jun*	20-May
15-Jun	15-Jun	12-Jun	18-Jun	10-Jun
20-Jul	13-Jul	17-Jul	10-Jul	15-Jul
17-Aug	18-Aug	07-Aug	14-Aug	05-Aug
21-Sep	20-Sep	19-Sep	11-Sep	02-Sep
12-Oct	12-Oct	09-Oct	01-Oct	-
14-Nov	15-Nov	-	-	04-Nov
14-Dec	-	-	-	-

Due to persistent bad weather conditions, no survey was carried out in December 2011.

(*) denotes a delay in the survey date into the following month due to persistent bad weather conditions.

After 2012, no survey was carried out between November and January.

No plankton samples were collected during 2013.

During November 2014, only a water quality survey was carried out as part of the annual quarterly programme.

No survey work was planned in October 2014.

Generally, samples were collected at different states of tide and at different depths to sample as much water as could potentially pass through the CW intake.

Baseline sampling sites (Table 2.2 and

Figure 2.1) were targeted as follows:

- site WQ2 and WQ6 were within NF zone, within approximately 0.5 - 1 km from the Power Station Site;
- sites WQ7, WQ8 and WQ9 covered an area proximal to the Power Station Site and are considered as MF, as is WQ5;

- two sites within the FF zone, between 5 and 6 km to the west and east of the Power Station Site and within 500 m from shore (sites WQ1 and WQ3); and
- a reference offshore control site along the 'central axis' (line due north of the Power Station Site), approximately 4 km offshore (site WQ4).

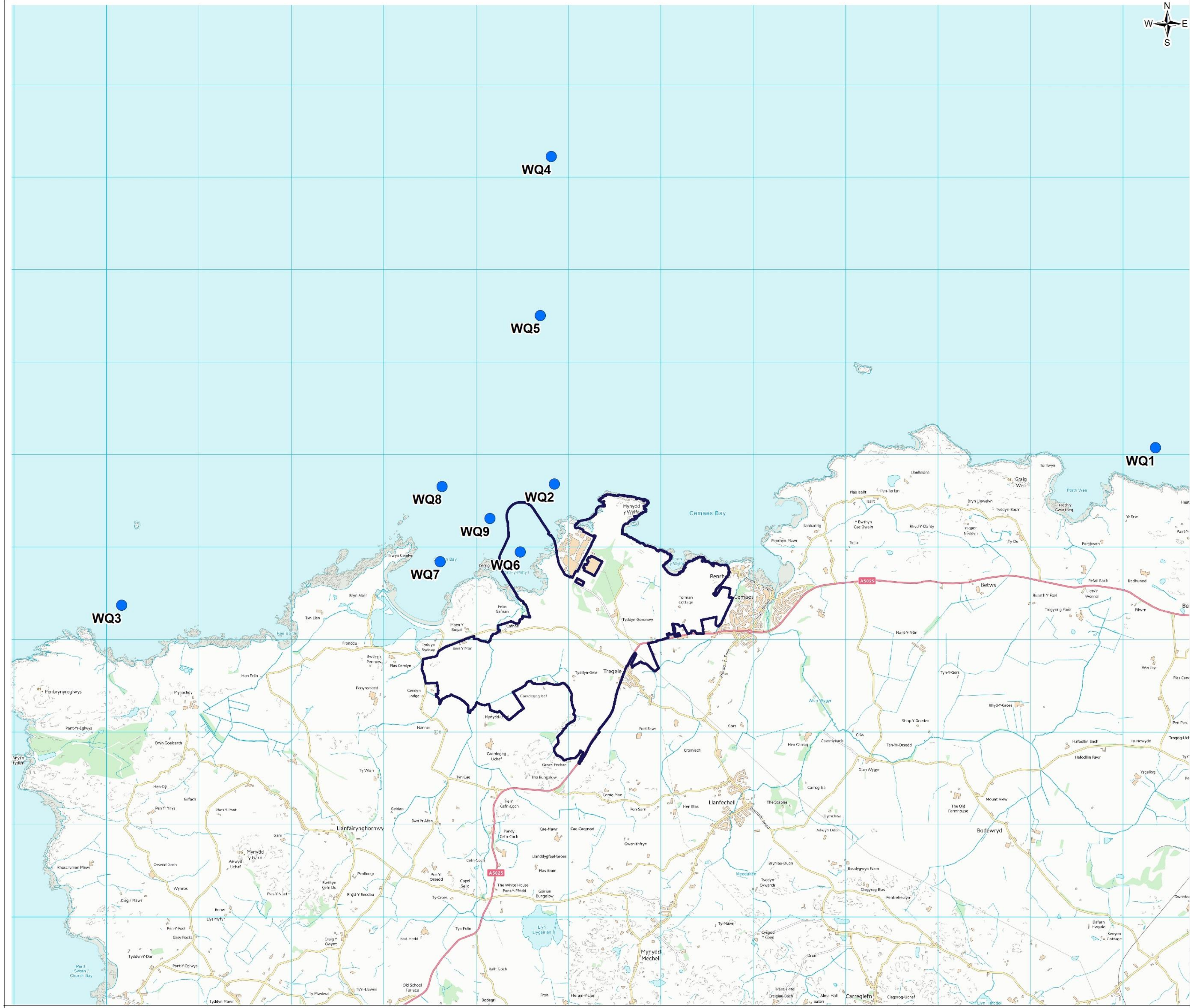
Table 2.2 : Target locations of sampling sites.

Site	Zone	Target Location
WQ1	Far Field	N 53° 25.710, W 04° 23.362
WQ2	Near Field	N 53° 25.379, W 04° 29.216
WQ3	Far Field	N 53° 24.584, W 04° 33.396
WQ4	Control Site	N 53° 27.287, W 04° 29.358
WQ5	Mid Field	N 53° 26.358, W 04° 29.411
WQ6	Near Field	N 53° 24.976, W 04° 29.562
WQ7	Mid Field	N 53° 24.905, W 04° 30.304
WQ8	Mid Field	N 53° 25.342, W 04° 30.310
WQ9	Mid Field	N 53° 25.165, W 04° 29.835

Note: Site WQ6 was included in the monitoring programme from August 2011. Sites WQ7, WQ8 and WQ9 were introduced in February 2014.

In addition to the baseline survey programme (reported in Sections 3, 8 and 9), two additional surveys were carried out within the vicinity of the existing power station in December 2015 and February 2016 and another one around the proposed disposal site at Holyhead North in October 2016. Results from these surveys are reported separately in Sections 4 and 5 respectively.

FIGURE 2-1



Contains public sector information licensed under the Open Government Licence v3.0

Legend

- Wylfa Newydd Development Area
- Water quality, phytoplankton and zooplankton baseline sampling sites

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
0	DEC 17	Initial Issue	VG	HY	RW	RB

JACOBS

Kenneth Dibben House, Enterprise Road, Southampton, SO16 7NS
Tel: +44(0)2380111250 Fax: +44(0)2380111251

Client

HORIZON NUCLEAR POWER

Project

WYLFA NEWYDD PROJECT
WATER QUALITY AND PLANKTON REPORT

Drawing Title

WATER QUALITY, PHYTOPLANKTON AND ZOOPLANKTON SAMPLING SITES

Drawing Status

Scale @ A3	1:40,000	DO NOT SCALE
Jacobs No.	60PO8099	
Client No.		
Drawing No.	60PO8007_AQE_REP_004_02_01	

3. Water Quality during the baseline monitoring programme

3.1 Introduction

This section presents results of the water quality surveys carried out from May 2010 to November 2014. A total of five sites (WQ1 – WQ5) were monitored from May 2010 to July 2011. In August 2011 an extra site (WQ6) was incorporated to the programme, to monitor the CW intake proposed location. In February 2014 another three sites (WQ7 – WQ9) were incorporated to the programme to increase resolution for the CW intake proposed location and to cover the vicinity of the MOLF development.

3.2 Methods

The majority of the surveys were carried out on board the local vessel 'SeeKat C' operating from Amlwch Port. However, due to technical difficulties, availability or the overall baseline monitoring programme, a reduced number of surveys were carried out on board of different vessels. All procedures and methods used were agreed with relevant stakeholders and statutory regulators (Environment Agency of Wales (EAW) and Countryside Council for Wales (CCW), collectively now known as Natural Resources Wales (NRW)).

Although instrumentation and method remained consistent throughout the monitoring programme, determinands analysed and total number of samples collected per site and tide were periodically reviewed and adjusted to avoid unnecessary sampling effort and to ensure the baseline programme was covering all necessary parameters needed for the final environmental assessment. Changes in the monitoring programme were agreed with all parties (including regulatory bodies) and are summarised in Section 3.2.2.

3.2.1 Determinands

3.2.1.1 Physico-chemical

The following physico-chemical parameters were measured *in situ* vertically at each site:

- pressure (depth);
- temperature;
- salinity (automatically calculated using the UNESCO algorithm (IOC, 2010);
- dissolved oxygen (DO) (% saturation and concentration);
- turbidity (measured using the nephelometric technique);
- chlorophyll in vivo;
- pH; and
- oxidation reduction potential (ORP), also referred in the literature as Redox.

3.2.1.2 Chemical and Biochemical

Although the number of samples, sites and frequency varied as a result of the monitoring programme reviews, the following group of determinands were monitored during the programme at different intervals (see Section 3.2.2):

- seawater parameters including pH, alkalinity, bromide, calcium, potassium, sodium and sulphate. The last four compounds were monitored in their total and dissolved fraction;
- total and dissolved organic carbon (TOC and DOC) and total suspended solids (TSS);
- biological and chemical oxygen demand (BOD and COD);
- nutrients, including phosphates, silicates, nitrates and nitrites;
- nitrogen (dissolved organic, inorganic and oxidised, Kjeldahl, ammoniacal and un-ionised ammonia);

- total and dissolved metals including arsenic, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, selenium, tin, vanadium and zinc;
- total petroleum hydrocarbons (TPHs);
- polycyclic aromatic hydrocarbons (PAHs);
- polychlorinated biphenyls (PCBs);
- volatile organic compounds (VOCs);
- phenolic compounds;
- chlorination by-products (CBPs) including trihalomethanes, haloacetonitriles, halophenols and haloacids;
- anticorrosive agents including hydrazine, ethanolamine and morpholine; and
- cyanide.

3.2.1.3 Radioisotopes

Radioisotope samples were analysed for:

- radioactivity: total α-radiation and total β-radiation;
- artificial radionuclides including Americium-241 (^{241}Am), Cobalt-60 (^{60}Co), Caesium-137 (^{137}Cs); and
- naturally occurring radionuclides including Sulphur-35 (^{35}S), Carbon-14 (^{14}C), Tritium (^{3}H), Actinium-228 (^{228}Ac), Bismuth-212 (^{212}Bi), Bismuth-214 (^{214}Bi), Potassium-40 (^{40}K), Lead-210 (^{210}Pb), Lead-212 (^{212}Pb), Lead-214 (^{214}Pb), Radium-226 (^{226}Ra), Thorium-234 (^{234}Th) and Uranium-235 (^{235}U).

3.2.2 Monitoring Programme

The monitoring programme and sampling regime were reviewed periodically to ensure all parameters needed for the environmental assessment were covered. All changes to the monitoring programme were previously consulted and agreed with regulators (NRW) and key stakeholders and were based on results, data analysis and the most up to date information available at the time.

Initially all sites included in the monitoring programme were sampled on a monthly basis. From 2012 onwards, after agreement with regulators, no survey was carried out between November and January. Five sites (WQ1 WQ5) were monitored from May 2010 to July 2011. In August 2011, a new site (WQ6) was incorporated in the monitoring programme to cover the CW intake proposed location. In 2013 sites WQ1 and WQ3 were dropped from the monitoring programme as it was considered that baseline data for these sites were sufficient. In February 2014, site WQ5 was also dropped from the monitoring programme, although another three sites (WQ7 – WQ9) were incorporated to increase the resolution around site WQ6 and to cover the area around the MOLF in Porth-y-pistyll (Figure 2.1). From the latter three sites, WQ7 was the only site where a full monitoring programme was carried out. Sites WQ8 and WQ9 were only monitored for physico-chemical parameters in the vertical water column.

Physico-chemical parameters (Section 3.2.1) were monitored at all sites visited and at each tidal state (flood and ebb) from May 2010 to April 2012, except from November 2011 to January 2012. During these months and after April 2012, physico-chemical parameters were monitored only at a single random tidal state. The exception to this was at WQ6 where from April 2012 to October 2013 physical parameters were still monitored on both tidal states; this was to ensure a better resolution in the most likely location for CW intake. From February 2014 onward, site WQ6 was monitored on a single random tidal state, however, sites WQ7, WQ8 and WQ9 were incorporated in the monitoring programme and monitored for physico-chemical parameters on a monthly basis (except in October 2014 when no survey was carried out) to increase the resolution around the preferred locations for the CW intake and MOLF. Chlorophyll in vivo and turbidity were monitored from May 2010 to October 2012, oxidation-reduction (Redox) potential was incorporated to the physico-chemical parameters in February 2013 while all other physico-chemical parameters (see Section 3.2.1) were measured for the duration of the monitoring programme.

Biochemical determinands (Section 3.2.1.2) (oxygen demand, pH, alkalinity, nutrients, suspended solids, total and dissolved organic carbon) were monitored at each tidal state (flood and ebb) from May 2010 to August 2012, except from November 2011 to January 2012. During these months, they were only monitored at a single random tidal state in line with the rationalisation of the plankton monitoring programme during the winter months. All biochemical determinands were monitored at all sites from May 2010 to April 2012, but from May to August 2012 were only monitored at site WQ6 in order to complete the first full monitoring year at this site. In February 2013 all biochemical determinands except suspended solids, total and dissolved organic carbon were reincorporated to the monitoring programme, although sites were only monitored at a single random tidal state, except at site WQ6 to increase the resolution within the Wylfa Newydd Development Area. In 2014, all sites monitored were sampled at a single random tidal state and from March 2014 the sampling frequency was reduced to a quarterly basis except at site WQ7 where monthly sampling continued in order to increase resolution in the area around the location for the MOLF. Although suspended solids, total and dissolved organic carbon were reincorporated to the list of determinands in February 2014, alkalinity and oxygen demand were excluded.

Chemical determinands (Section 3.2.1.2), excluding PAHs, PCBs, VOCs, CBPs and the anticorrosive agents, were monitored on a monthly basis at all sites visited from May 2010 to April 2012. From May to August 2012, only site WQ6 was monitored in order to complete a full monitoring year. During the first 16 months (May 2010 to August 2011), all chemical determinands were monitored at both flood and ebb tide. From September 2011 onward, chemical determinands were monitored only at one random tide, as no significant difference was found between tides (see Section 3.3.2). Chemical determinands were not monitored during 2013 as enough data were collected in previous years. From February 2014 to November 2014 chemical determinands were reintroduced in the monitoring programme in order to validate all data collected in previous years. However, in light of results reported in previous years, only the dissolved fraction was monitored (except for mercury). During this period, only four sites were monitored (WQ2, WQ4, WQ6 and WQ7) and from April 2014 onward, all monitored sites, except WQ7 were monitored on a quarterly basis. The sampling regime at site WQ7 was kept on a monthly basis to increase the resolution within the Wylfa Newydd Development Area.

PAHs, PCBs, VOCs were incorporated to the list of determinands in August 2010. All these organic compounds were monitored monthly from August to November 2010. In light of the results reported, monitoring frequency was reduced to a quarterly regime. Also in light of the results reported, PAHs, PCBs and VOCs were dropped from the monitoring programme in May 2012. In February 2014 all these compounds were reintroduced in the monitoring programme in order to validate all data collected in previous years. The sampling frequency, number of sites and duration were the same as for the other chemical determinands (see above).

Anticorrosive agents (hydrazine, ethanolamine and morpholine) were introduced into the list of determinands in February 2012, while CBPs were introduced in May 2012. These two groups of determinands were monitored on a monthly basis until October 2013.

Radioisotopes (Section 3.2.1.3) were monitored from July 2010 on a monthly basis until August 2011. Given the results reported after the first year (Jacobs, 2011), monitoring frequency was reduced to a quarterly regime from August 2011 onwards and was last monitored in February 2012.

3.2.3 Sampling Methodology

All physical parameters (Section 3.2.1) were measured *in situ* using either a YSI 6600v2 or an Idronaut Ocean Seven 316 Plus. The YSI sonde was fitted with sensors for non-vented pressure, temperature, conductivity, pH, turbidity, optical dissolved oxygen and chlorophyll. The Idronaut sonde was fitted with a non-vented pressure sensor, highly accurate temperature and conductivity sensors, highly responsive pH and ORP sensors and a pressure-compensated polarographic dissolved oxygen sensor.

The instrument was laboratory-calibrated for each parameter prior to departing to site and field-calibrated for pressure on arrival at site. Pre-survey field quality control (QC) checks were performed and recorded for salinity, dissolved oxygen and pH. Post survey QC checks were also performed to confirm that no drift had occurred in instrument parameters during the survey, ensuring data quality.

Each sensor was calibrated using the following standards/methods:

- conductivity sensor was calibrated using Atlantic seawater (salinity = 35 ± 2%) traceable to International Standards;
- pH sensor was calibrated using *Reagecon*® buffered standards, pH 4, pH 7 and pH 10 (3 point calibration);
- DO sensor was calibrated in air (100% of saturation) and pressure compensated when required;
- turbidity sensor was calibrated using distilled water (0 (Nephelometric Turbidity Units) NTU) and *Reagecon*® turbidity standards of 126 NTU and 1000 NTU (three-point calibration); and
- chlorophyll sensor was calibrated by performing a one-point calibration with deionised water which zeros the relative fluorescence unit (RFU) and the chlorophyll concentration.

At each sampling site, the survey vessel held position whilst the sonde was lowered through the water column at an approximate rate of 10 cm s^{-1} to allow for the response time of all sensors. After March 2011, all sensors were interfaced with HYDROpro™. This software records all parameters measured directly to a PC every second and georeferences all data using a highly accurate Global Positioning System (GPS) unit. Before March 2011, all physical parameters were logged directly to the instrument's internal memory every two seconds and positions were recorded using a handheld GPS.

While vertical profiles were taken, water samples were collected for chemical, biochemical and radioisotope analysis (Sections 3.2.1.2 and 3.2.1.3). The sampling method used in all surveys for chemical analysis was the commonly used spot (bottle) sampling, followed by extraction and instrumental analysis at the laboratory. This methodology is well established and validated. However, it should be noted that spot samples are collected at a given location, depth and time, and that the information obtained is unique to the place and time selected (Madrid and Zayas, 2007). Biochemical samples were collected using an integrated water sampling technique (Lund tube), which allows collection of water samples from across a depth range (surface to 10 m depth).

Samples for chemical analysis were collected from 1 m below the surface using a sampling can and from mid-depth using a Niskin bottle, biochemical samples were collected using a Lund tube and radioisotope samples were collected from 1 m below the surface using the sampling can.

The Lund tube consists of a weighted, open-ended tube which is lowered slowly through the water column. The tube is then sealed, capturing an integrated sample of water from the surface to 10 m depth. The water captured in the tube was retrieved and homogenised into a container before decanting into sample bottles.

The Niskin bottle is a device that has stoppers on both ends, which are held in place by springs. It is prepared by cocking open both ends of the bottle before being attached to a rope (marked at 1 m intervals) and lowered to the desired depth. A small weight, the "messenger", is then attached to the rope and released. The messenger on reaching the Niskin bottle triggers the closing mechanism, releasing the two stoppers and capturing a sample of the water from the given depth. This allows samples to be taken at a specific depth without contamination from water at shallower depths.

All samples collected were decanted into clean containers, preserved where required, labelled and appropriately stored before being sent for analysis at a UKAS accredited laboratory.

3.2.4 Sample Analysis

3.2.4.1 Limit of Detection (LoD) and Minimum Reportable Values (MRV)

Limit of detection (LoD; expressed as a concentration) is derived from the smallest concentration that can be detected with a reasonable level of confidence for the given analytical procedure (IUPAC, 1997).

Minimum Reportable Values (MRV) are minimum concentrations selected for reporting purposes which are often higher than the statistically derived method LoD and allow higher confidence that a sample is different from a blank sample containing no determinand of interest. MRVs are set by the analysing laboratory and are used to provide consistency of reporting as well as an allowance for sample variation.

The LoD and MRV are assigned values and are based upon ideal analysis conditions, although some factors such as matrix contamination or insufficient volume may result in a rise in MRV due to the need for dilution. Also, some analytical techniques applied to saline water require substantial dilution (which may vary between samples) to reduce the chloride/saline interference. Dilution factors are incorporated in the MRV, which for some techniques can result in a high MRV.

3.2.4.2 Legislative Standards

Where applicable, results have been compared to marine Environmental Quality Standards (EQSs). EQS values have been derived from *The River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive (WFD)) (England and Wales) Directions 2010.* The 2010 Directions aid the implementation of the *WFD (2000/60/EC),* the *Dangerous Substances Directive (2006/11/EC – Codified version)* and the *Priority Substances Directive (2008/105/EC)*, which lay down EQSs in accordance with the provisions and objectives of the WFD.

The *Dangerous Substances Directive*, repealed by the WFD in 2013, classifies substances under List I and List II. List I substances are those deemed to be particularly dangerous to the environment owing to their toxicity, persistence and bioaccumulation. List II substances, while less dangerous, are still considered to have a deleterious effect on the aquatic environment. The *Priority Substances Directive* replaces Annex X of the WFD and lays down EQSs for 33 substances (including priority substances and other pollutants).

Although most of the EQSs stated in this report are the Annual Average EQSs (AA-EQS) for 'other surface waters', the Maximum Allowable Concentrations EQSs (MAC-EQS) for 'other surface waters' have also been used when applicable.

Other relevant legislation considered in this document includes:

- *Shellfish Water Directive (2006/113/EEC), the Surface Waters (Shellfish) (Classification) (Amendment) Regulations 2009 (S.I. 2009 No. 1266)* and *The Surface Waters (Shellfish) Directions 2010;*
- *Bathing Water Directive (2006/7/EC)* and *The Bathing Water Regulations 2013 (S.I. 2013 No. 1675);*
- *The Surface Waters (Dangerous Substances) (Classification) Regulations 1997 (S.I. 1997 No. 2560)* and *1998 (S.I. 1998 No. 389);*
- *Department of the Environment Circular 7/89;* and
- *QA/QC Directive (2009/90/EC)* and the *Chemical Analysis of Water Status (Technical specifications) Directions 2011.*

The legislative standards detailed above are valid for the baseline monitoring period (May 2010 – November 2014). However, it should be noted that in Wales *The Water Environment (Water Framework Directive) (England and Wales) (Amendment) Regulation 2015 (S.I. 2015 No. 1623*) and *The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015* was adopted on 22 December 2015

3.3 Results

3.3.1 Physico-Chemical Parameters

Some of the available water column vertical profiles can be found in Appendix A. Most of the vertical profiles were recorded for each month at all sites, although technical issues with the sonde or weather conditions prevented some vertical profiles from being recorded. All issues are summarised below:

- June 2010: Technical issues with the sonde prevented the recording of any data;
- February 2011: Due to internal memory shortage, some vertical profiles were not recorded;
- April 2011: Technical issues with the internal battery prevented recording some of the vertical profiles;
- September 2011: pH profiles were disregarded due to sensor malfunction during the survey;

- December 2011: No vertical profiles are available due to persistent bad weather conditions during this month;
- February 2013: ORP sensor was not installed until later this month (after survey was carried out);
- March 2013: dissolved oxygen data not available due to a technical problem with the sensor;
- April 2013: the reference sensor was broken at the beginning of the survey, consequently only temperature and salinity were recorded;
- May and June 2013: due to a technical problem with the internal configuration the pH sensor did not record decimal values. Unfortunately, decimal values were displayed while vertical profiles were taken but not recorded within the dataset found in the internal memory. All values were recorded as 8 or 9;
- August 2013: DO and ORP sensors did not pass the internal QA procedure (>20% drift was recorded at the end of the survey);
- April 2014: Technical problems with the internal battery only allowed recording of profiles at site WQ4;
- May 2014: ORP profiles are not available as the sonde used (YSI6600v2) was not fitted with it an ORP sensor; and
- November 2014: no vertical profile recorded at site WQ7 due to bad weather condition at the time of sampling. ORP data not available for any site due to technical problems with the sensor.

When no data were available for a particular site, limited data (temperature and salinity) were extracted where possible from the YSI600XLM sonde used during the plankton surveys. Maximum, minimum and mean values recorded for each survey can be found in Appendix B. All data available are summarised below.

3.3.1.1 Temperature

Monthly variations of the temperature recorded within the water column during each survey (from May 2010 to November 2014) are given in Appendix B, Table B.1 and shown below in Figure 3.1.

Annual variability recorded in the survey area (north Anglesey) shows the expected pattern with the highest temperatures recorded in July or August and the lowest temperatures recorded in January or February. However, the lowest temperature recorded during the baseline monitoring programme was found in March 2013, while the highest temperature was recorded in August 2014.

Overall, temperature values were found to be stable throughout the water column. The increment or decrement found within the water column (between surface and seabed) was generally lower than 0.4ºC and in some months even lower than 0.1ºC. This implies a well-mixed water column around the north Anglesey area. Although some profiles showed a decrease or increase of around 0.5ºC within the first 1 m, these differences are considered due to a slow response time[4] of the temperature sensor rather than an actual variation. All vertical profiles can be found in Appendix A.

In general, no seasonal thermal stratification was observed at any site. However, a degree of stratification was occasionally observed at some sites. A summary of these observations is listed below:

- November 2010 at site WQ2;
- December 2010 at site WQ4;
- March 2011 at site WQ2;
- October 2011 at site WQ6;
- June 2012 at site WQ6;
- February 2013 at site WQ2;

[4] Although generally speaking a temperature sensor has a quick response time, when the sensor is submerged in water, this response time increases due to change in the environment (air-water) and big differences in temperature. If not enough time is left for the temperature sensor to adjust to the new environment, false readings will take place until the sensor adjusts.

- May 2013 at site WQ6;
- August 2013 at site WQ2;
- September 2013 at site WQ2;
- October 2013 at site WQ2;
- May 2014 at site WQ6;
- June 2014 at site WQ7;
- July 2014 at sites WQ6, WQ7, WQ8 and WQ9;
- August 2014 at site WQ9; and
- November 2014 at site WQ9.

Temperature values observed between sites were comparable, and the small differences were most likely due to daily temperature variations rather than site specific or tidal variations.

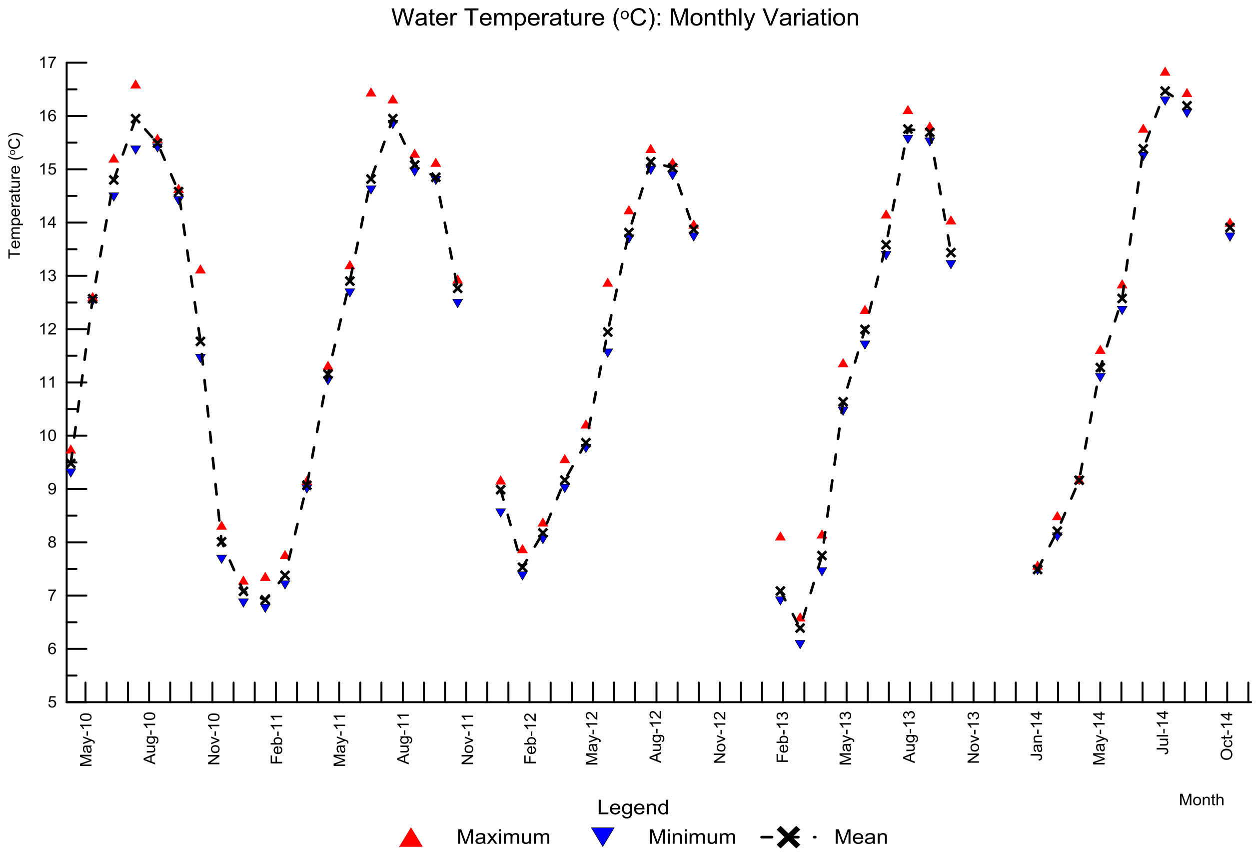


Figure 3.1 : Water temperatures recorded monthly along the north Anglesey coast between May 2010 and November 2014.

3.3.1.2 Salinity

Monthly variations for salinity recorded within the water column during each survey, from May 2010 to November 2014, are given in Appendix B, Table B.2 and shown below in Figure 3.2.

Salinity values recorded in the survey area ranged between a minimum of 32.80 in September 2012 and a maximum of 35.29 in May 2011. The mean value recorded from May 2010 to November 2014 was 34.29. All salinity values recorded throughout the duration of the monitoring programme are in line with the expected values for coastal waters (as reported by Turekian (1976)) around the Irish Sea.

Generally, salinity values were found to be stable throughout the water column, however, very weak haloclines (strong vertical salinity gradient) were observed at different sites and in different months. All values recorded indicate a well-mixed water body, however in March and April 2012, signs of water stratification were observed at all sites on both ebb and flood tides and at some sites in May 2012, March 2013 and May 2014. All vertical profiles can be found in Appendix A.

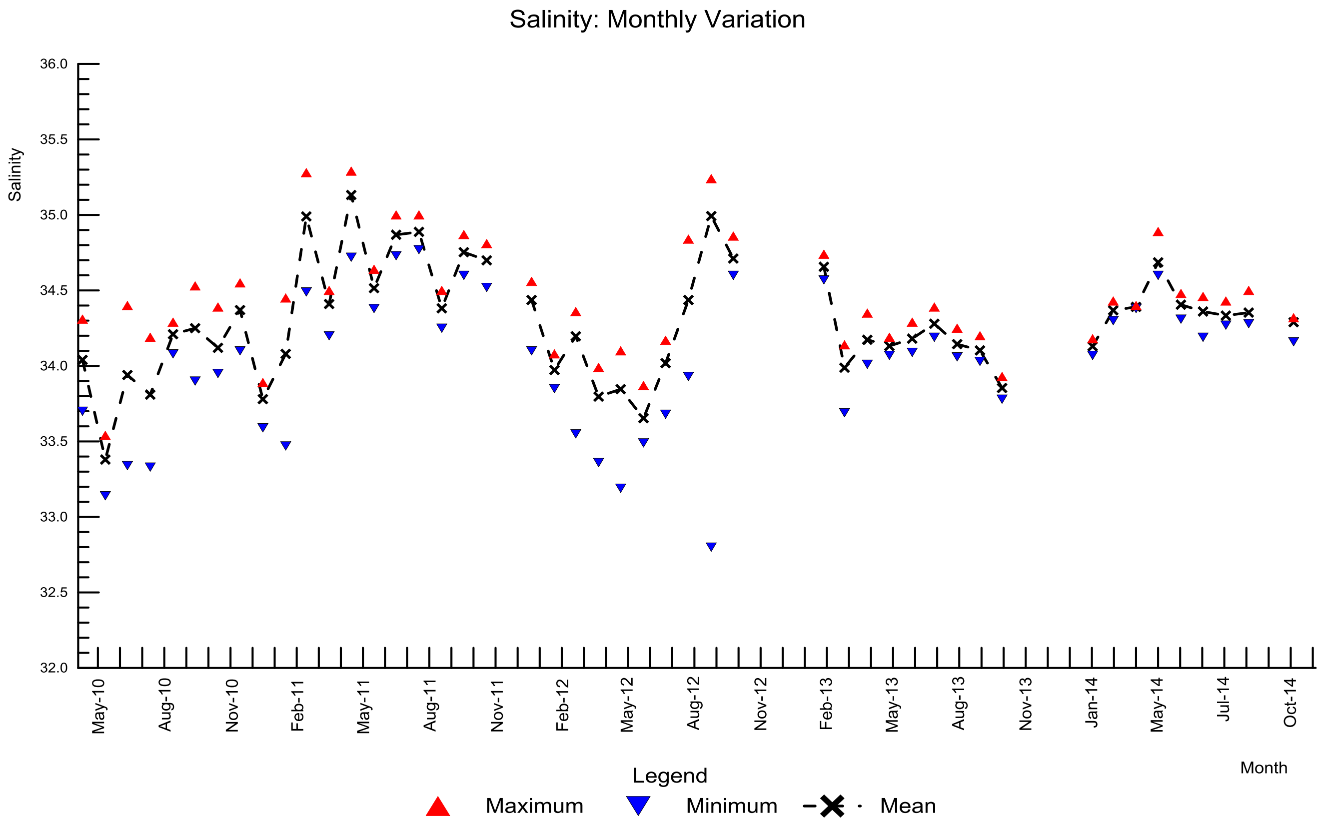


Figure 3.2 : Seawater salinity recorded monthly along the north Anglesey coast between May 2010 and November 2014.

3.3.1.3 Dissolved Oxygen

Monthly values of DO (saturation levels and concentrations) recorded during each survey are given in Appendix B, Table B.3 and Table B.4 and presented below in Figure 3.3 and Figure 3.4.

DO saturation levels from May 2010 to November 2014 were considered high, ranging from 90.2%, recorded in September 2014, to 121.1%, recorded in October 2013. The mean value recorded from May 2010 to November 2014 was 100.6%. The DO saturation levels were found to be similar at all sites, however slight variations (generally lower than 10%) between sites were sometimes observed, especially in July and October 2013. These variations were probably driven by primary production as well as daily water temperature variation, tidal currents and other environmental parameters.

DO concentration observed during the same period ranged from 7.19 mg L^{-1}, recorded in September 2014, to 10.69 mg L^{-1}, recorded in May 2013. The mean value recorded from May 2010 to November 2014 was 8.79 mg L^{-1}. These ranges indicate high DO standards according to the directions[5] given from the Environment Agency in connection with the WFD (2000/60/EC) and other directives.

[5] The River Basin Districts Typology, Standards and Groundwater Threshold values (Water Framework Directive) (England and Wales) Directions 2010, came into force on 4 August 2010. This Direction stabilised high standard for DO ≥ 5.7 mg L^{-1} in transitional and coastal waters with salinity normalised to 35.

Annual variability recorded in the survey area shows the expected pattern with the highest DO concentrations recorded during the winter months, when the water temperature is lower[6], and the lowest DO concentrations were recorded during the summer months, when the water temperature is higher.

All vertical profiles can be found in Appendix A.

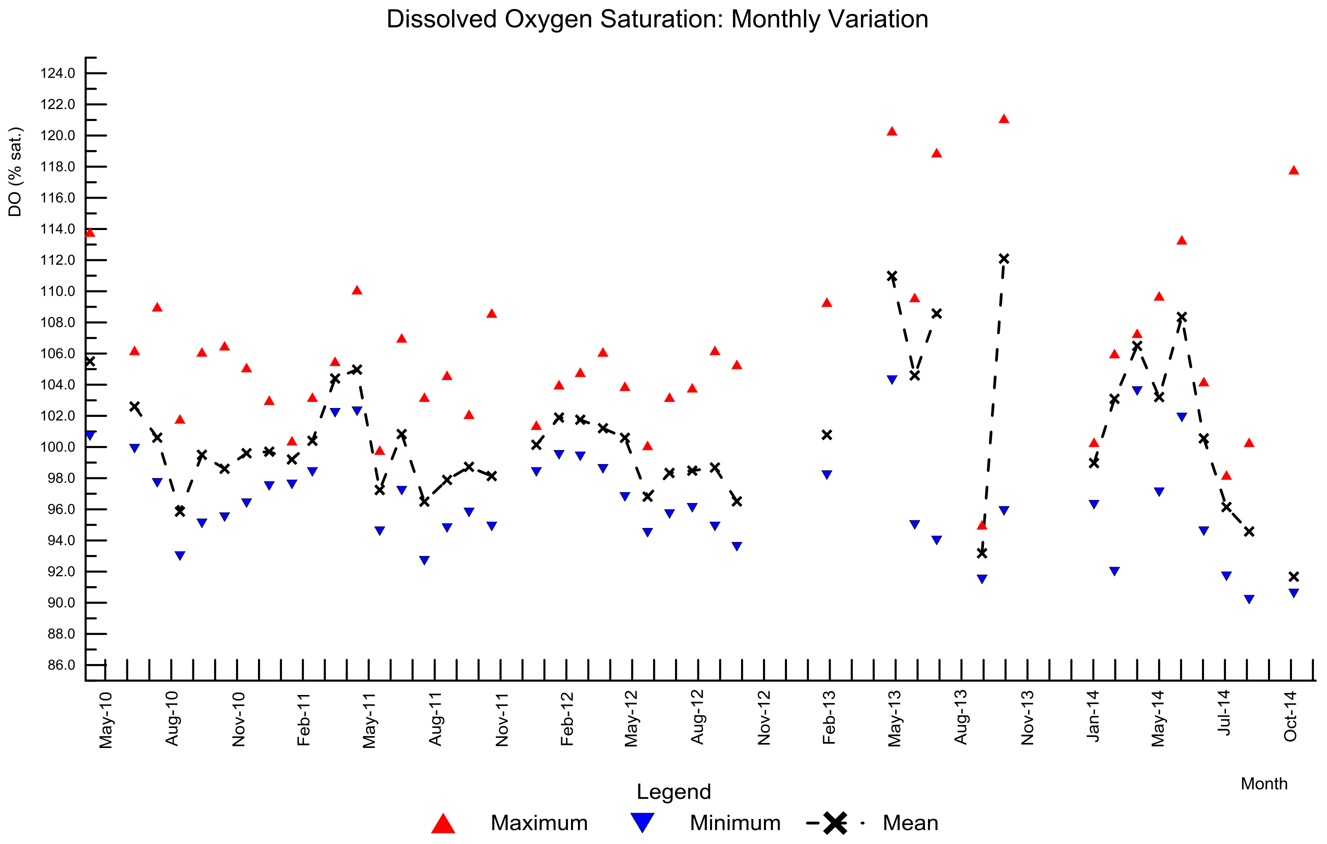


Figure 3.3 : Dissolved oxygen saturation levels (%) of the water column recorded monthly along north Anglesey coast between May 2010 and November 2014.

[6] Thermodynamically, the solubility of a gas, including oxygen, is inversely dependent on temperature. Therefore, an increase in temperature results in a decrease in oxygen (or any other gas) solubility in water, while a decrease in temperature results in an increase of oxygen solubility in water. Although this factor may influence DO concentrations it is unlikely to be the sole reason for variation, as other factors including mixing (turbulence) are also likely to affect concentrations.

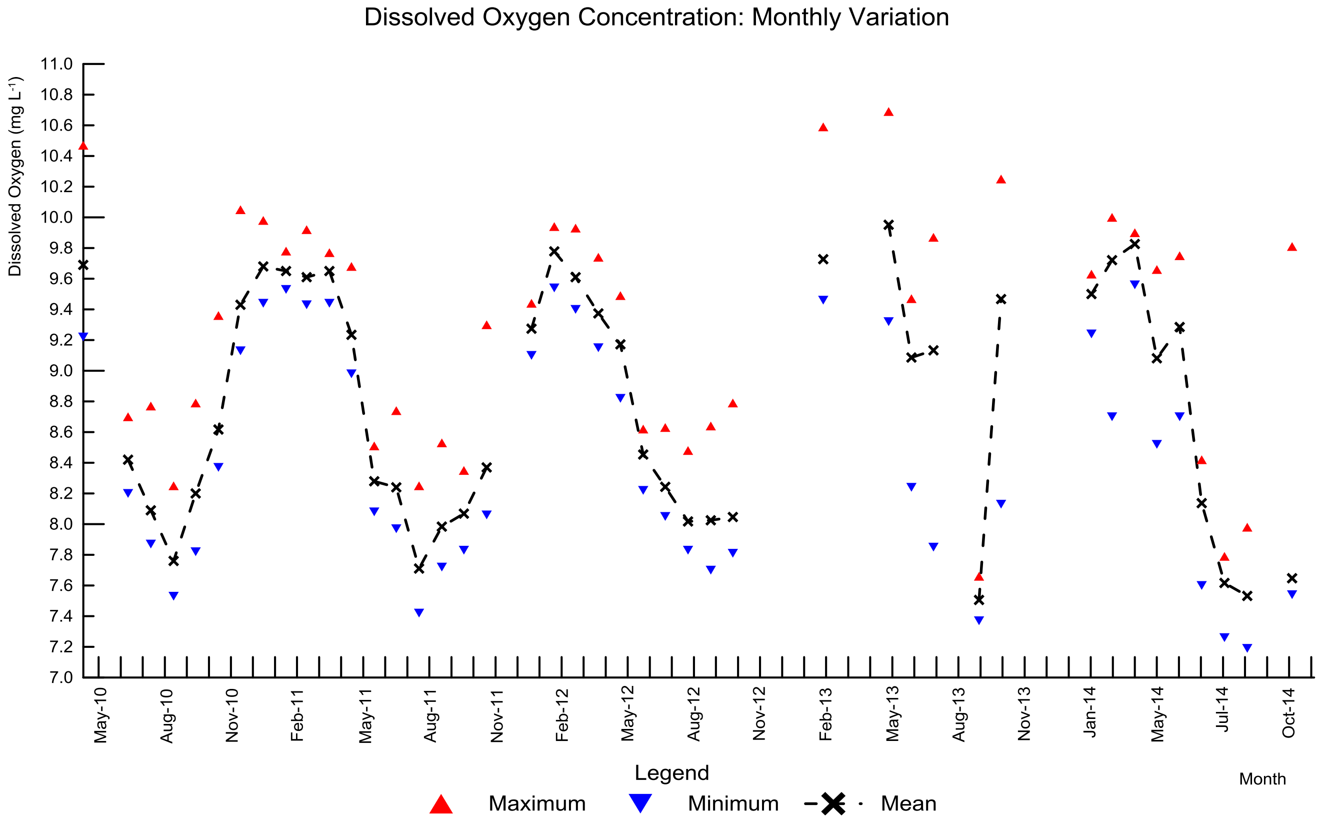


Figure 3.4 : Dissolved oxygen concentrations (mg L-1) in the water column recorded monthly along the north Anglesey coast between May 2010 and November 2014.

3.3.1.4 pH

Monthly values for pH recorded during each survey, from May 2010 to November 2014, are given in Appendix B, Table B.5 and presented below in Figure 3.5.

pH values ranged between 6.94, recorded in June 2011, and 8.46, recorded in July 2013 and June 2014.

Vertical profiles showed little variation in pH values with depth. pH values recorded each month were comparable between sites, except at site WQ1 where during several months the pH recorded was notably different (ΔpH=0.3) than at all other sites.

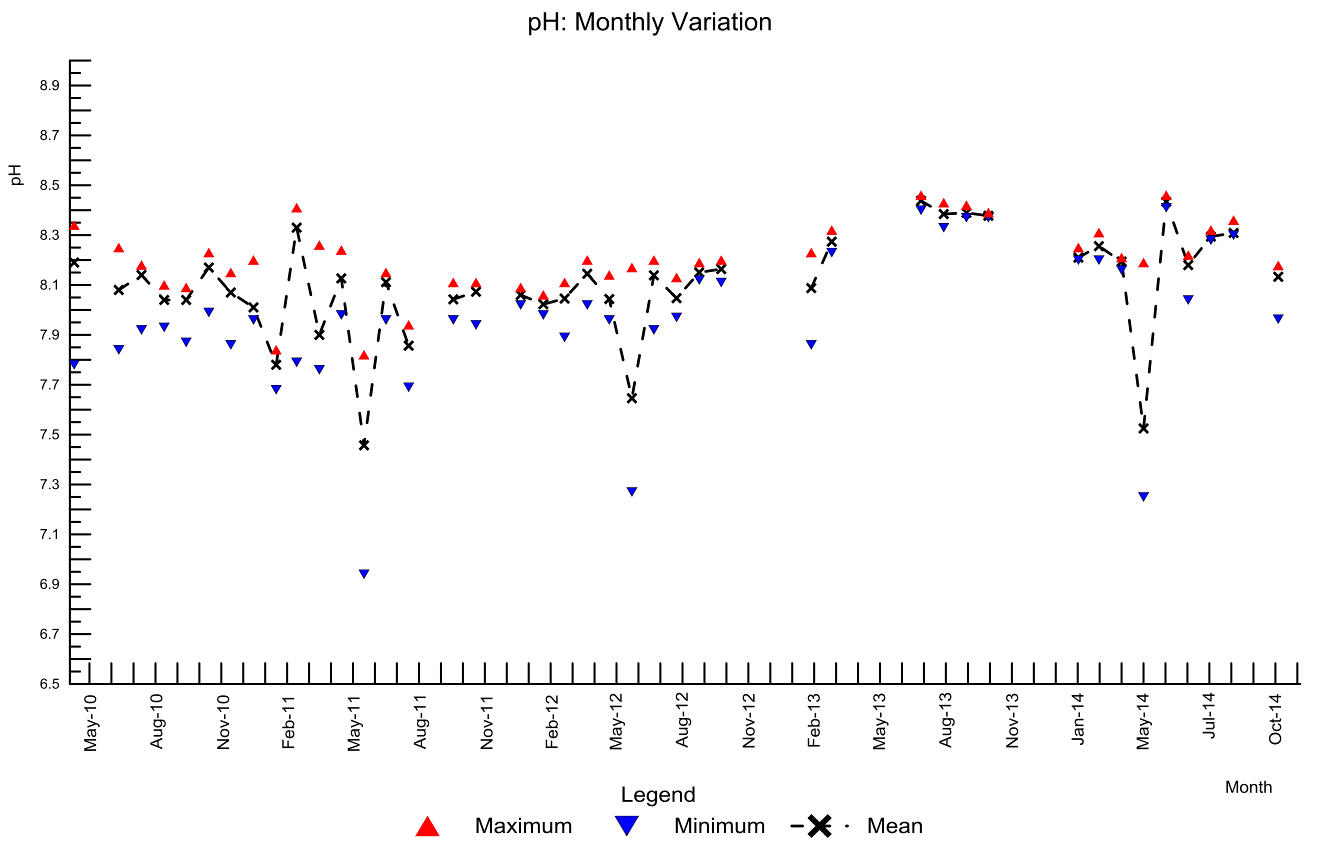


Figure 3.5 : Seawater pH values recorded monthly along the north Anglesey coast between May 2010 and November 2014.

3.3.1.5 Chlorophyll in vivo

Chlorophyll data obtained with the YSI 6025 sensor should only be used as an indicative measurement and not as an exact value. The values of chlorophyll obtained from in vivo fluorescence measurement will always be less reliable than determinations made on molecular extraction described in standard methods (YSI, 2006).

As part of the monitoring programme, Jacobs collected specific samples at each location for pigment analysis. Results from these analyses are presented and discussed in Section 5.

Chlorophyll concentrations were generally higher within 5 m of the water surface (some months within the first 10 m). Generally, no regular pattern was evident through the vertical column at any site or tidal state. Highest values were recorded near the surface in May, July and August 2010, May, June and July 2011 and January and May 2012 (Figure 3.6). Higher values are always expected in surface waters between May and September, as this period falls within the phytoplankton growing season (from March to October). Chlorophyll values reported in January 2012 at site WQ1 on the ebb tide were considerably higher than expected for this month. Although no apparent reason has been found, it should be noted that values recorded in vivo are not as reliable as results from molecular extraction of chlorophyll-a (chl-a) (YSI, 2006) and therefore should only be used as indicative. All vertical profiles available can be found in Appendix A.

The mean values for each month in the area surveyed were below 10 µg L^{-1}, above which, according to the WFD phytoplankton multi-metric classification tool kit (SNIFFER, 2008), is the indicator value for chlorophyll bloom. Monthly means ranged between 0.20 µg L^{-1} (recorded in December 2010) and 4.17 µg L^{-1} (recorded in May 2012).

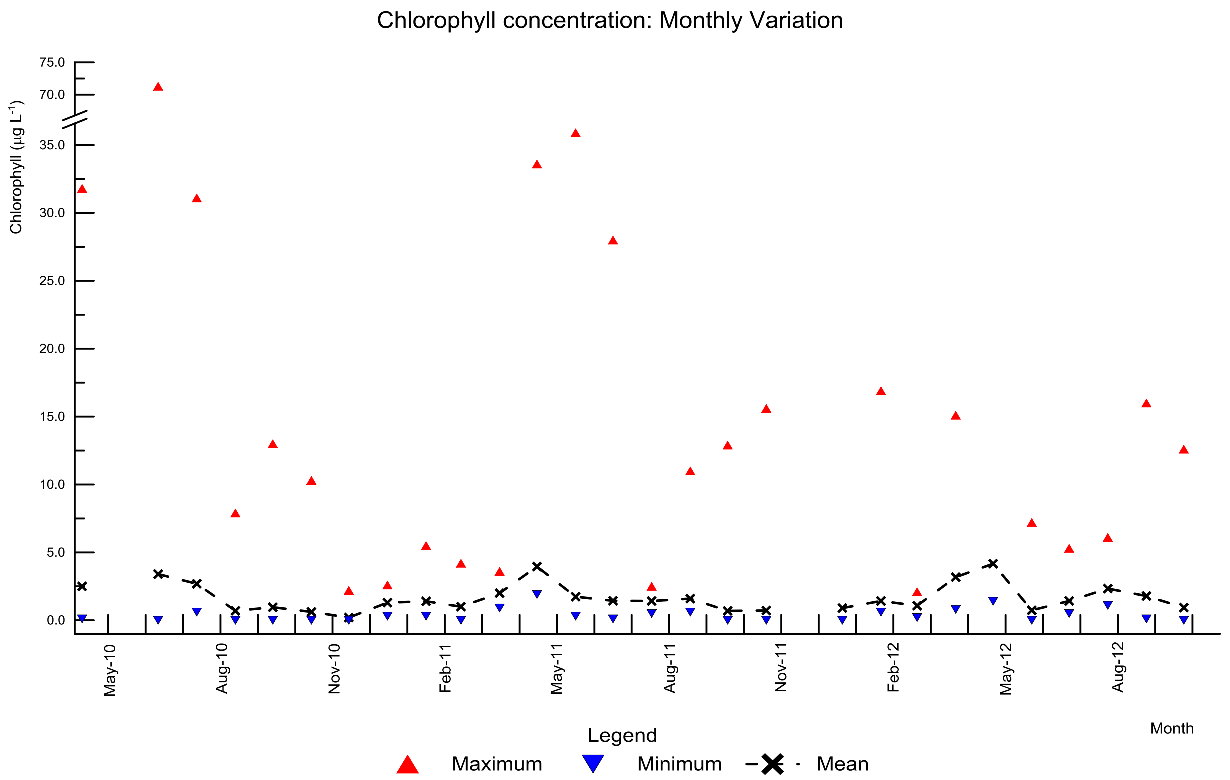


Figure 3.6 : Monthly chlorophyll *in vivo* concentrations recorded along the north Anglesey coast between May 2010 and October 2012.

3.3.1.6 Turbidity

Although no particular pattern in turbidity was found at any site or tidal state, vertical profiles showed relatively stable values through the water column, with variation generally lower than six NTU in total at each site. There were some exceptions recorded in August, November and December 2010, May, June and September 2011 and August 2012, when variation was higher. Turbidity values were generally higher at the surface or near the seabed, which is expected due to water turbulence, suspended solids, organic matter, etc. at the surface and sediment resuspension near the seabed. All vertical profiles available can be found in Appendix A.

Monthly values for turbidity recorded during each survey, from May 2010 to October 2012, are given in Appendix B, Table B.7 and presented below in Figure 3.7. Turbidity data for this period varied between 0 NTU and 30 NTU, although monthly means for the survey area ranged between 0.8 NTU and 9.9 NTU, with an inter-annual mean of 3.5 NTU.

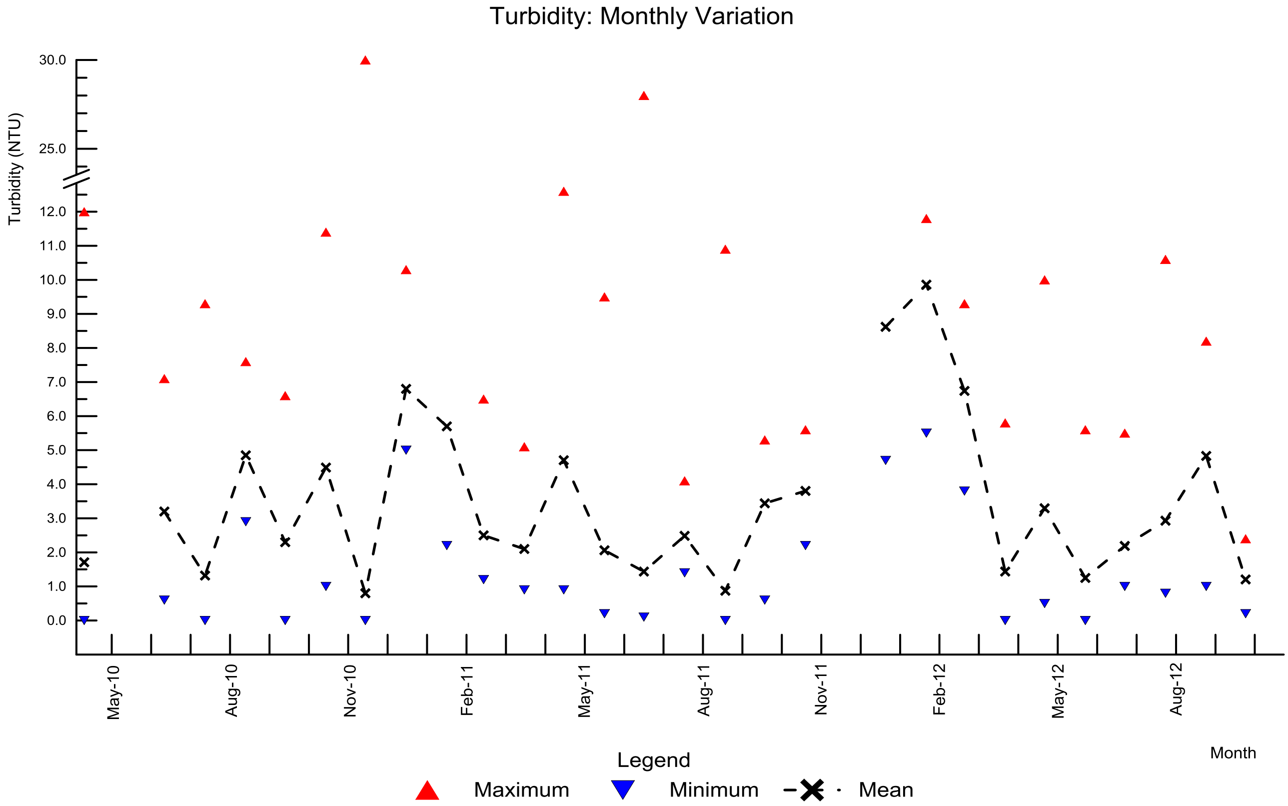


Figure 3.7 : Turbidity monthly variation along the north Anglesey coast between May 2010 and October 2012.

3.3.1.7 Oxidation Reduction Potential (ORP) or Redox

ORP monitoring began in March 2013 and therefore no data from previous years are available. Monthly values for ORP recorded during each survey, from March 2013 to September 2014, are given in Appendix B, Table B.8 and presented below in Figure 3.8.

Values recorded from March 2013 to September 2014 ranged from 262.5 mV, recorded in October 2013, to 464.8 mV, recorded in March 2014. The mean value recorded from March 2013 to September 2014 was 354.9 mV. These values were in line with those expected in coastal seawater (Cooper, 1937).

Vertical profiles at all sites showed very little variation with depth. Vertical variations of 10 mV or less were recorded at most sites, with higher vertical variation (less than 22 mV) only occasionally recorded at some sites. All vertical profiles available can be found in Appendix A.

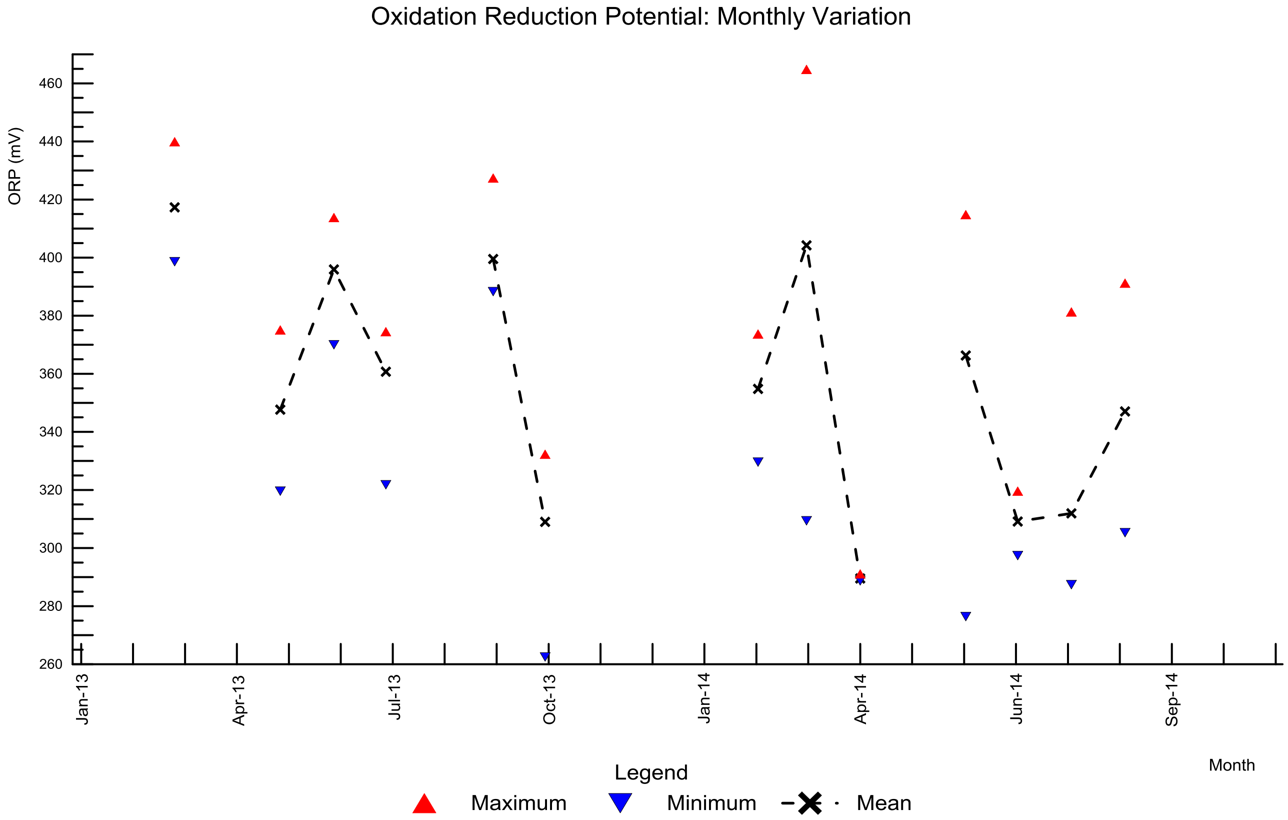


Figure 3.8 : ORP monthly variation along the north Anglesey coast between May 2010 and October 2012.

3.3.2 Laboratory Analysis Results

Even though weak stratification was found occasionally throughout the surveyed area, most temperature and salinity vertical profiles (see Sections 3.3.1.1 and 3.3.1.2) recorded between May 2010 and November 2014 indicated a very well-mixed water body. Therefore, it is acceptable to consider all the surveyed sites as part of one single water body. Consequently, despite the limitations of the spot sampling technique (see Section 3.2.3), monthly concentrations in this water body can be estimated as the arithmetic mean of all sites and depth sample concentrations from the corresponding calendar month. To further corroborate this assumption, a statistical analysis was run using all available results reported during the first 12 months (May 2010 – April 2011). The statistical analysis results (Appendix C) showed no significant differences between sites, depths or tides and therefore the assumption of one single water body within the survey area was considered sound.

The above approach does have an implicit limitation; the direct dependence on the number of samples collected each month. Due to the changes in the monitoring programme (see Section 3.2.2), the number of samples collected each month varied and therefore the monthly concentration calculated for some months might not fully reflect the concentration expected for the survey area as a whole. For instance, monthly concentrations calculated for the water body could have been based on 24 samples or only one sample (depending on the month collected). The total number of samples collected and used for each month was as follows:

- from May 2010 to July 2011 the monthly concentrations calculated for the water body were based on 20 samples;
- in August 2011 the monthly concentrations calculated for the water body were based on 24 samples;
- from September 2011 to April 2012 the monthly concentrations calculated for the water body were based on 12 samples;
- from May 2012 to August 2012 the monthly concentrations calculated for the water body were based on two or 12 samples, depending on the determinand;

- in September and October 2012 the monthly concentrations calculated for the water body were based on 12 samples;
- from February 2013 to October 2013 the monthly concentrations calculated for the water body were based on four or five samples, depending on the determinand; and
- from February 2014 to November 2014 the monthly concentrations calculated for the water body were based on one or four samples depending on the month (quarterly sampling adopted at some sites).

The arithmetic means were calculated using all concentrations available from each calendar month and following the QA/QC Directive (2009/90/EC) and Directions 2011. This Directive states that when chemicals in a given sample are below the limit of quantification, the measurement results shall be set to half of the value of the limit of quantification as an equivalent to mean values. If the value of the measured results is below the limits of quantification, the value shall be referred to as "less than limit of quantification".

All arithmetic means calculated for each compound as well as the annual average can be found in Appendix D and are summarised below. There are no data available for some determinands in October 2010 (nutrients and biochemical determinands) due to some samples being lost in transit to the laboratory. Also, in December 2011 no survey was carried out due to persistent bad weather conditions.

3.3.2.1 Physico-Chemical determinands

3.3.2.1.1 pH

Monthly average pH values reported from May 2010 to November 2014 ranged between 7.27 (May 2014) and 8.42 (June 2014). Annual averages were reported as follows:

- 8.07 (May 2010 to December 2010);
- 8.04 (January 2011 to November 2011);
- 8.04 (January 2012 to August 2012);
- 8.03 (February 2013 to October 2013); and
- 8.12 (February 2014 to November 2014).

All values recorded were within the range expected for coastal waters and within the guideline values for the Shellfish Waters Directive (2006/113/EC) of pH 7.0 to 9.0. All monthly means and annual averages can be found in Appendix D, Table D.1.

3.3.2.1.2 Alkalinity

Monthly average alkalinity measured to pH 4.5 as $CaCO_3$ from May 2010 to October 2013 ranged between 71.5 mg L^{-1} (September 2010) and 78.6 mg L^{-1} (June 2013). Alkalinity was not monitored during 2014. The annual averages were consistent throughout the monitoring programme and they were reported as follows:

- 73.3 mg L^{-1} (May 2010 to December 2010);
- 74.8 mg L^{-1} (January 2011 to November 2011);
- 75.0 mg L^{-1} (January 2012 to August 2012); and
- 74.8 mg L^{-1} (February 2013 to October 2013).

The inter-annual average alkalinity from May 2010 to October 2013 was 74.6 mg L^{-1}. Monthly and annual average results for alkalinity can be found in Appendix D, Table D.1. Alkalinity data are not available for samples collected in October 2010 (samples lost in transit to the laboratory).

3.3.2.1.3 Oxygen demand (BOD and COD)

Biological oxygen demand (BOD) average values for each month from May 2010 to October 2013 were lower than 2.9 mg L^{-1}. BOD was not monitored during 2014. The MRV was set as 2.90 mg L^{-1} from May 2010 to May

2011, except in June and July 2010 where MRV was set as 1.00 mg L^{-1}. From June 2011 onwards, the MRV was again set as 1.00 mg L^{-1} (more information about MRV can be found in Section 3.2.4). Annual averages were reported as follows:

- <2.90 mg L^{-1} (May 2010 to December 2010);
- 1.45 mg L^{-1} (January 2011 to November 2011)[7] ;
- 1.67 mg L^{-1} (January 2012 to August 2012); and
- <1.00 mg L^{-1} (February 2013 to October 2013).

Monthly average chemical oxygen demand (COD) was reported as being below the MRV (300, 500 or 600 mg L^{-1}) each month except in May 2010, when the mean value was reported as 745.6 mg L^{-1}. MRV values for COD varied each month depending on the dilution level needed (see Section 3.2.4). Annual averages for COD were found below MRV each year. COD was not monitored during 2014. All data available for BOD and COD can be found in Appendix D, Table D.1. BOD or COD data are not available for samples collected in October 2010 (samples lost in transit to the laboratory).

3.3.2.1.4 Organic Carbon (TOC and DOC)

Monthly average total organic carbon (TOC) values ranged between <1.0 mg L^{-1} (several months) to 20.95 mg L^{-1} (March 2011). In July 2014, TOC was reported as 55 mg L^{-1} (based on one sample only). However, the laboratory has confirmed that the elevated value might have been a consequence of matrix contamination/interference. As a result, the value was not used to calculate the corresponding annual average. TOC was not monitored during 2013. All other annual averages were reported as follows:

- 1.25 mg L^{-1} (May 2010 to December 2010);
- 4.47 mg L^{-1} (January 2011 to November 2011);
- 1.26 mg L^{-1} (January 2012 to August 2012); and
- 1.28 mg L^{-1} (February 2014 to November 2014).

Monthly average dissolved organic carbon (DOC) values ranged between 0.56 mg L^{-1} (March 2014) to 6.02 mg L^{-1} (June 2014). DOC was not monitored during 2013. All other annual averages were reported as follows:

- 1.39 mg L^{-1} (May 2010 to December 2010);
- 1.30 mg L^{-1} (January 2011 to November 2011);
- 1.23 mg L^{-1} (January 2012 to August 2012); and
- 1.40 mg L^{-1} (February 2014 to November 2014).

All monthly and annual averages can be found in Appendix D, Table D.1.

3.3.2.1.5 Total Suspended Solids (TSS)

Monthly average TSS concentrations varied from 3.2 mg L^{-1} (April 2011) to 21.6 mg L^{-1} (March 2014). TSS was not monitored during 2013. All other annual averages were reported as follows:

- 6.4 mg L^{-1} (May 2010 to December 2010);
- 6.1 mg L^{-1} (January 2011 to November 2011);
- 7.1 mg L^{-1} (January 2012 to August 2012); and
- 13.0 mg L^{-1} (February 2014 to November 2014).

All monthly and annual average results can be found in Appendix D, Table D.1.

---

[7] From January to May 2011 the MRV was set at 2.90 mg L^{-1}, while from June to November 2011 the MRV was lowered to 1.00 mg L^{-1}.Thefore the annual average calculated could also be set as <2.90 mg L^{-1}.

3.3.2.2 Cations and Anions

All concentrations measured were reported within the expected values for coastal waters and with no significant variations throughout the monitoring programme. Annual averages are presented in Table 3.1. Cations and anions were not monitored during 2013 and only the dissolved fractions were monitored in 2014. All monthly averages and annual averages can be found in Appendix D, Table D.2.

Table 3.1 : Cation and anion annual average concentrations. Monitoring years are defined in Section 2.

Compound		Units	2010	2011	2012	2014
Bromide		mg L^{-1}	66.1	68.2	68.3	64.5
Calcium	Total	mg L^{-1}	399	403	413	-
	Dissolved	mg L^{-1}	392	404	414	409
Potassium	Total	mg L^{-1}	374	377	368	-
	Dissolved	mg L^{-1}	372	377	363	389
Sodium	Total	mg L^{-1}	10128	10481	10466	-
	Dissolved	mg L^{-1}	10178	10478	10372	9929
Sulphate as (SO_4)	Total	mg L^{-1}	2548	2623	2659	-
	Dissolved	mg L^{-1}	2565	2637	2626	2535

3.3.2.3 Nutrients

Nutrient concentrations were determined for each month collected, except October 2010 when the samples were lost in transit to the laboratory. All monthly and annual averages can be found in Appendix D, Table D.3.

Monthly average concentrations for nitrogen (as N) were reported between 0.136 mg L^{-1} (June 2011 and July 2011) and 0.371 mg L^{-1} (July 2014), except in October 2011 where the average concentration was reported as below MRV (0.1 mg L^{-1}). Nitrogen (as N) was not reported in 2013. All other annual averages were reported as follows:

- 0.126 mg L^{-1} (May 2010 to December 2010);
- 0.170 mg L^{-1} (January 2011 to November 2011);
- 0.195 mg L^{-1} (January 2012 to August 2012); and
- 0.256 mg L^{-1} (February 2014 to November 2014).

Nitrogen oxidised (dissolved and total) monthly average concentrations were consistently reported as below MRV (0.1 mg L^{-1} and 0.2 mg L^{-1}, respectively) with some exceptions (December 2010, January and February 2011, February and March 2012, March 2013, February, March and April 2014 for the dissolved fraction and September 2011, January, February and March 2012 for the total fraction). The total fraction was not monitored in 2013 and 2014. Annual averages remained below MRV each year.

Nitrogen Kjeldahl (which is calculated from nitrogen total as N and nitrogen total oxidised) was reported as <1.00 mg L^{-1} each month, from May 2010 to August 2012 and from February 2014 to November 2014. Nitrogen Kjeldahl was not monitored in 2013.

Monthly averages for ammoniacal nitrogen (as N) for both the total and dissolved fraction, were mostly reported as below MRV (<0.01 mg L^{-1} or <0.02 mg L^{-1}, respectively). Dissolved ammoniacal nitrogen was monitored from May 2010 to November 2014, while total ammoniacal nitrogen was only monitored from May 2010 to August 2012. The monthly averages for the dissolved fraction reported above MRV ranged from 0.011 mg L^{-1} to 0.076 mg L^{-1}, while the monthly averages reported above MRV for the total fraction ranged between 0.013 mg L^{-1} and 0.021 mg L^{-1}. Annual averages for ammoniacal nitrogen (dissolved and total) were calculated as below MRV each year.

Un-ionised ammonia concentrations (calculated from temperature, pH and ammoniacal nitrogen) remained well below the relevant EQS of 21 µg L^{-1} each month with monthly average values calculated between <0.231 µg L^{-1} and 2.330 µg L^{-1}. Annual average concentrations for un-ionised ammonia were reported as follows:

- <0.476 µg L^{-1} (May 2010 to December 2010);
- <0.504 µg L^{-1} (January 2011 to December 2011);
- <0.435 µg L^{-1} (January 2012 to August 2012);
- <0.472 µg L^{-1} (February 2013 to October 2013); and
- <0.958 µg L^{-1} (February 2014 to November 2014).

Monthly average concentrations for total organic nitrogen (calculated from total nitrogen as N, total nitrogen oxidised and ammoniacal nitrogen) were reported between <0.924 mg L^{-1} and <0.990 mg L^{-1}. Values from February 2013 to October 2013 were not reported as total nitrogen was not monitored during the quoted period. All other annual averages were calculated as follows:

- <0.986 mg L^{-1} (May 2010 to December 2010);
- <0.985 mg L^{-1} (January 2011 to December 2011);
- <0.980 mg L^{-1} (January 2012 to August 2012); and
- <0.973 mg L^{-1} (February 2014 to November 2014).

Monthly average concentrations for nitrogen inorganic (calculated from nitrogen, total oxidised and ammoniacal nitrogen) were reported between <0.120 mg L^{-1} and <0.221 mg L^{-1}. The range of this variation is due to changes in the MRV value for nitrogen total oxidised, from 0.2 mg L^{-1} (from May 2010 to August 2011) to 0.1 mg L^{-1} from September 2011 onward. Annual averages for nitrogen inorganic were calculated as <0.210 mg L^{-1} for 2010 and 2011, and <0.120 mg L^{-1} from 2012 to 2014.

Nitrite concentrations (monthly averages) ranged between <0.004 mg L^{-1} (MRV) and 0.0148 mg L^{-1} (reported in October 2011). Annual averages for this compound were reported as follows:

- 0.0046 mg L^{-1} (May 2010 to December 2010);
- 0.0050 mg L^{-1} (January 2011 to December 2011);
- <0.004 mg L^{-1} (January 2012 to August 2012);
- <0.004 mg L^{-1} (February 2013 to October 2013); and
- 0.0061 mg L^{-1} (February 2014 to November 2014).

Monthly average nitrate concentrations (calculated from nitrite and nitrogen, total oxidised) ranged from <0.085 mg L^{-1} to 0.138 mg L^{-1}. Annual averages remained as <0.10 mg L^{-1} each year.

Orthophosphate (also known as soluble reactive phosphorus) monthly average concentrations ranged between <0.010 mg L^{-1} (July and September 2014) and 0.032 mg L^{-1} (February 2012). Annual averages were reported as follows:

- 0.020 mg L^{-1} (May 2010 to December 2010);
- 0.021 mg L^{-1} (January 2011 to December 2011);
- 0.021 mg L^{-1} (January 2012 to August 2012);
- 0.019 mg L^{-1} (February 2013 to October 2013), and
- 0.015 mg L^{-1} (February 2014 to November 2014).

Monthly average silicate concentrations ranged from <0.200 mg L^{-1} (several months) to 0.450 mg L^{-1} (in February 2014) with annual averages reported as <0.200 mg L^{-1} (from 2010 to 2013) and 0.243 mg L^{-1} in 2014.

3.3.2.4 Metals

Metals and heavy metals are found throughout the marine environment both as a result of natural background level and anthropogenic input. Monthly (or seasonal) differences in these concentrations are normally expected as environmental conditions (temperature, salinity, light, etc.) change through the year. It should be noted that monthly variation does not follow any particular pattern (Appendix C). All metal samples were analysed for both dissolved and total fraction from May 2010 to August 2012. Metals were not monitored in 2013, and they were reintroduced in the list of determinands in February 2014, however, only the dissolved fractions were monitored in 2014. All arithmetic means calculated for each month and the annual averages can be found in Appendix D., Table D.4.

All metals (except mercury in October 2010) were consistently reported as below their relevant EQS. Monthly, as well as annual average concentrations for boron, nickel, copper, zinc, arsenic and lead were all found to range within the expected values for coastal water (Turekian, 1976). Vanadium, manganese, cobalt, selenium and tin were consistently reported as below the MRV. Most of the concentrations reported for chromium, iron, cadmium and mercury were found below MRV, however some exceptions were reported.

Mercury concentration (only the total fraction) was recorded above the relevant EQS (EQS-MAC = 0.07µg L^{-1}) in October 2010 (monthly average = 0.091 µg L^{-1}). The annual average for the first year (May 2010 to April 2011) was found below the relevant EQS[8].

Chromium was reported above the MRV in December 2010 (6.81 µg L^{-1} for the dissolved fraction and 1.23 µg L^{-1} for the total fraction), May 2011 (0.66 µg L^{-1} for the total fraction), September 2011 (3.75 µg L^{-1} for the dissolved fraction and 3.89 µg L^{-1} for the total fraction) and February 2012 (0.62 µg L^{-1} for the total fraction). In December 2010, extremely high concentrations were reported at site WQ1 (116 µg L^{-1} for the dissolved fraction and 19.8 µg L^{-1} for the total fraction). Also, during this survey, a high concentration was reported at site WQ3 (12.4 µg L^{-1} for the dissolved fraction only). The fact that the highest concentrations were reported only for the dissolved fraction but not for the total fraction implies a likely cross-contamination from the preservatives used to fix the mercury samples (potassium dichromate and nitric acid).

Cadmium was only recorded above the MRV (0.04 µg L^{-1}) in September 2011 (0.078 µg L^{-1} for the dissolved fraction and 0.06 µg L^{-1} for the total fraction) and November 2011 (0.085 µg L^{-1} for the dissolved fraction and 0.09 µg L^{-1} for the total fraction). In September 2011, cadmium was reported in most samples collected, while in November 2011, it was only reported in a few samples. Annual averages for both fractions (total and dissolved) remained below MRV.

Iron was only monitored in 2014 and all monthly values were reported below the MRV, except in February (215 µg L^{-1}) and May (271 µg L^{-1}), with both values well below the EQS (1000 µg L^{-1}).

3.3.2.5 Organic compounds

3.3.2.5.1 Total Petroleum Hydrocarbons

All arithmetic monthly means for total petroleum hydrocarbons (TPH) were consistently found to be below the MRV (0.2 mg L^{-1}). TPHs were not monitored in 2013. Monthly and annual averages can be found in Appendix D, Table D.5.

3.3.2.5.2 Polycyclic Aromatic Hydrocarbons and Polychlorinated Biphenyls

Concentrations of all polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) measured were always found to be below the MRV (0.001 µg L^{-1}, 0.002 µg L^{-1} or 0.01 µg L^{-1} depending on the compound). PAHs and PCBs data were collected monthly from August 2010 to November 2010. In light of the results found during these four months (below MRV), the monitoring frequency for these compounds was reduced to a quarterly basis until May 2012. PAHs and PCBs were not monitored again until February 2014, when they were

[8] Although according to The River Basin Districts Typology, Standards and Groundwater Threshold values (Water Framework Directive) (England and Wales) Directions 2010, from August 2010 mercury EQS should be calculated from biota samples (20 µg kg^{-1} of prey tissue), the AA-EQS of 0.05 µg L^{-1} can still be used to assess compliance in the long term.

reintroduced in the monitoring programme and monitored monthly until November 2014 (see Section 3.2.2). All arithmetic means calculated for PAHs and PCBs as well as annual averages can be found in Appendix D, Table D.5.

3.3.2.5.3 Volatile Organic Compounds

Although some compounds (toluene, bromoform, ethylbenzene, dimethylbenzene, 1,3-dichloropropene and di-2-ethylhexyl phthalate) were occasionally reported marginally over the MRV, VOCs were generally found below MRV. All annual averages were reported as below MRV.

Data for VOCs were recorded monthly from August to November 2010. In light of the results (below MRV), the monitoring frequency was reduced to a quarterly basis until May 2012. VOCs were not monitored again until February 2014, when they were reintroduced and monitored monthly until November 2014 (see Section 3.2.2). Fifteen new compounds, including di-2-ethylhexyl phthalate (DEHP), were introduced to the list of determinands in 2014. All arithmetic monthly means calculated for each VOC as well as annual averages are given in Appendix D, Table D.6.

3.3.2.5.4 Phenols

Although the majority of phenolic compounds were reported as below the MRV in all samples, 2-methylphenol, 4-methylphenol and 4-chloro-3-methylphenol were occasionally reported marginally above the MRV. All arithmetic means and annual averages calculated for each phenol compound can be found in Appendix D, Table D.7. Phenols were not monitored in 2013.

2-methylphenol and 4-methylphenol are widely occurring natural and manufactured compounds, while 4-chloro-3-methylphenol is an antiseptic manufactured compound. Monthly averages for 2-methylphenol and 4-methylphenol remained below their MRV (0.02 µg L^{-1}), except in January 2011, where the mean concentration of 4 methylphenol was reported as 0.48 µg L^{-1} (well below the relevant EQS) and June 2011, where the mean concentration of 2-methylphenol was reported as 0.064 µg L^{-1} (also well below the relevant EQS). 4-chloro-3-methylphenol was frequently reported between May 2011 and April 2012. The maximum monthly average reported during that period was 0.231 µg L^{-1}, well below the EQS (40 µg L^{-1}).

Phenol was detected in most samples. Nevertheless, monthly average concentrations (between <0.05 µg L^{-1} and 0.27 µg L^{-1}) remained well below the relevant EQS (7.7 µg L^{-1}).

3.3.2.5.5 Chlorination By-Products (CBPs)

Four groups (trihalomethanes, haloacetonitriles, halophenols and haloacids) have been monitored on a monthly basis from May 2012 to October 2013. Monthly averages and the annual average for each compound can be found in Appendix D, Table D.8.

All haloacetonitrile and halophenol compounds analysed were reported as below the LoD (1 ng L^{-1}). Also, dibromochloromethane, monobromoacetic acid, dichloroacetic acid, bromate, 2-bromocyclohexanol and 1,2-dibromocyclohexanol were consistently found below the same LoD (see Table D.8, Appendix D).

Monthly average concentrations reported for bromoform, chloroform, bromodichloromethane, dibromoacetic acid, bromochloroacetic acid and monochloroacetic acid were found above the LoD. The range of values reported for these compounds were as follows:

- bromoform: 3.7 ng L^{-1} – 24.0 ng L^{-1};
- chloroform: 2.3 ng L^{-1} – 41.3 ng L^{-1};
- bromodichloromethane: 1.9 ng L^{-1} – 9.6 ng L^{-1};
- dibromoacetic acid: 2.0 ng L^{-1} – 23.0 ng L^{-1};
- bromochloroacetic acid: <1.0 ng L^{-1} – 8.9 ng L^{-1}; and
- monochloroacetic acid: 1.8 ng L^{-1} – 24.3 ng L^{-1}.

Values reported for these compounds were considered low in comparison with levels reported around other power station outfalls. For example, according to Jenner, *et al*., (1997) and BEEMS, (2011), the mean bromoform concentration found in effluents of 10 different coastal power stations (in the UK, France and the Netherlands) was 16.32 ± 2.10 µg L^{-1} (16320 ± 2100 ng L^{-1}). Also, the mean concentration reported for dibromoacetonitrile (second highest concentration reported by Jenner, *et al*., (1997)) was 1.48 ± 0.58 µg L^{-1} (1480 ± 580 ng L^{-1}) while this compound was consistently reported as below LoD from May 2012 to October 2013.

3.3.2.6 Anticorrosive

Three anticorrosive compounds (hydrazine, ethanolamine and morpholine) were monitored on a monthly basis from February 2012 to October 2013, and they were consistently reported as below the LoD (0.1 µg L^{-1}). All monthly averages and the annual averages can be found in Appendix D, Table D.8.

3.3.2.7 Cyanide

Cyanide was only monitored from February to November 2014. All results were reported below their MRV (0.5 mg L^{-1} for total cyanide as CN and 0.005 mg L^{-1} for free cyanide as CN).

3.3.2.8 Radioisotopes

The majority of the individual radioisotopes analysed between July 2010 and February 2012 were reported below the LoD for both the particulate and the filtered fractions. The LoD value varies between samples and for gamma data was calculated as defined by Currie (1968) and Gilmore & Hemingway (1995). For other radiochemical analyses, LoD was calculated as defined by Currie (1968).

Caesium-137 (^{137}Cs) was the only artificial radionuclide occasionally reported above LoD. The other two artificial radionuclides monitored, (Americium-241 (^{241}Am) and Cobalt-60 (^{60}Co)) were consistently reported below LoD. Positive results (above LoD) for ^{137}Cs were reported as follows:

- Filtrate fraction (LoD reported between 0.0008 and 0.0020 Bq mL^{-1}):
  - November 2010: one out of 10 samples reported as 0.0012 Bq mL^{-1}. All other samples reported as below LoD.
  - January 2011: six out of 10 samples reported between 0.00068 and 0.00600 Bq mL^{-1}. All other samples reported as below LoD.
  - February 2011: one out of 10 samples reported as 0.0012 Bq mL^{-1}. All other samples reported as below LoD.
  - November 2011: one out of six samples reported as 0.0006 Bq mL^{-1}. All other samples reported as below LoD.
- Particulate fraction (LoD reported between 0.00003 and 0.0008 Bq mL^{-1}):
  - February 2011: two out of 10 samples reported as 0.000021 and 0.000026 Bq mL^{-1}. All other samples reported as below LoD.
  - February 2012: one out of 10 samples reported as 0.00002 Bq mL^{-1}. All other samples reported as below LoD.

^{3}H, ^{14}C, ^{35}S, ^{212}Bi, ^{40}K, ^{212}Pb and ^{214}Pb were also occasionally reported, however, it must be noted that these are naturally occurring radionuclides and therefore concentrations reported might have been a combined effect between natural (background concentrations) and anthropogenic activities.

α and β radiation were analysed monthly between July 2010 and August 2011. In light of the results reported, monitoring frequency was reduced to a quarterly basis after August 2011 and stopped after February 2012.

α radiation was reported as below LoD for the majority of samples, with very few exceptions (one sample in July 2010, three samples in October 2010, one sample in January 2011 and two samples in February 2012). α radiation reported in these samples was marginally above LoD, with monthly averages constantly reported as below LoD.

Levels of β radiation reported in most samples (Figure 3.9) are comparable to the data reported by the Environment Agency and Food Standards Agency in their annual Radioactivity in Food and the Environment (RIFE) reports[9]. High levels of radiation were reported in a few samples collected in November 2010 and February 2012, with monthly averages (28.3 Bq L^{-1} and 27.3 Bq L^{-1} respectively) above the average value reported by the Environment Agency between 2000 and 2011 (10.4 Bq L^{-1}at Cemaes Bay; 13.9 Bq L^{-1} at Cemlyn Bay). Nonetheless, annual averages for 2010 and 2011 were reported at similar levels to data reported in the RIFE-16 and RIFE-17 report (Cefas, 2011 and 2012). All data available for β radiation around Wylfa Head are presented in Figure 3.10.

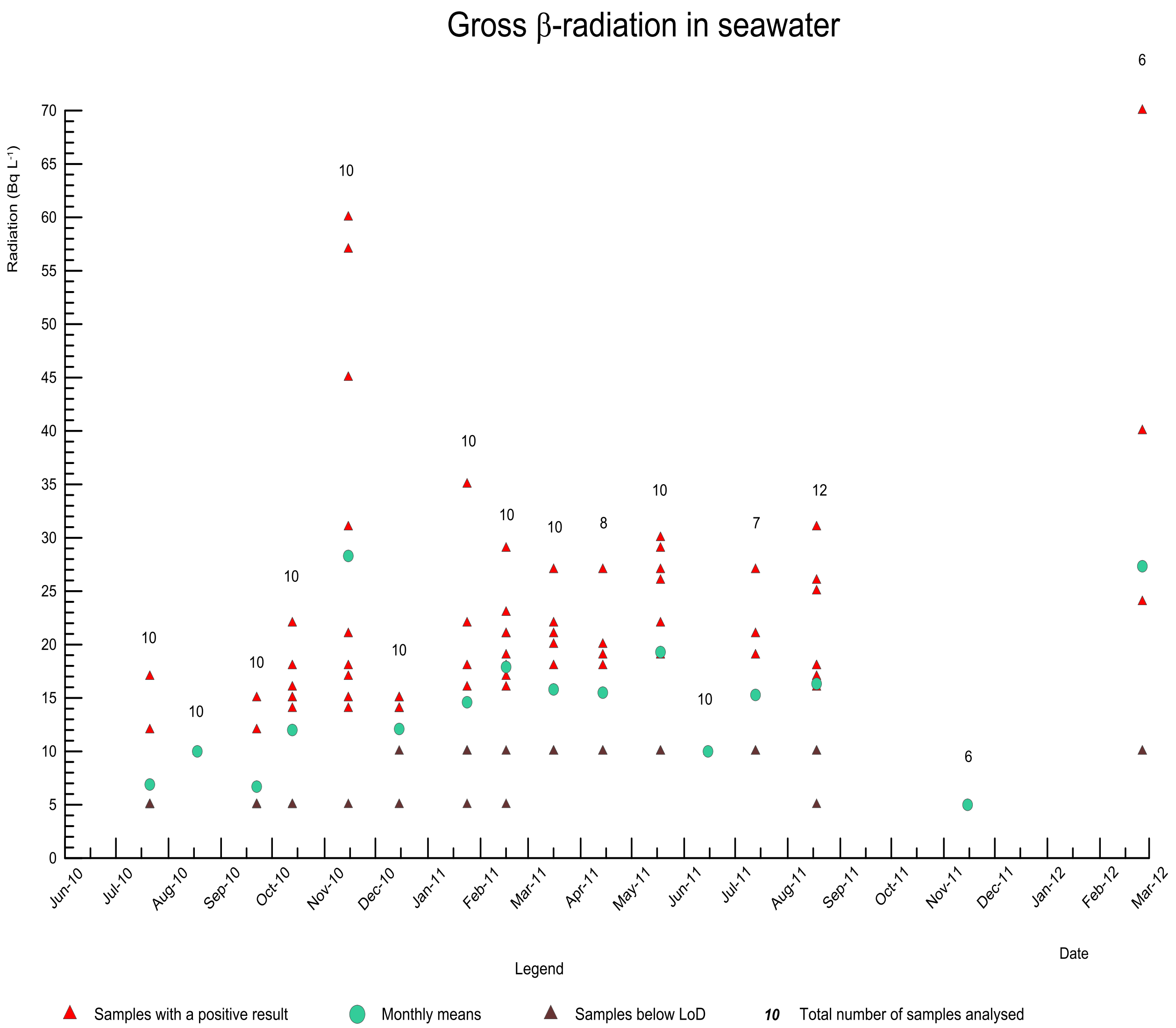


Figure 3.9 : β-radiation levels detected in individual samples (triangles), monthly mean values (circles) and number of samples analysed between July 2010 and February 2012. All samples collected by Jacobs during the monthly WQ surveys.

[9] RIFE data from 2000 to 2009 were provided by the Environment Agency, while data for 2010 and 2011 were extracted from the annual reports RIFE-16 and RIFE-17 (Cefas, 2011 and 2012)

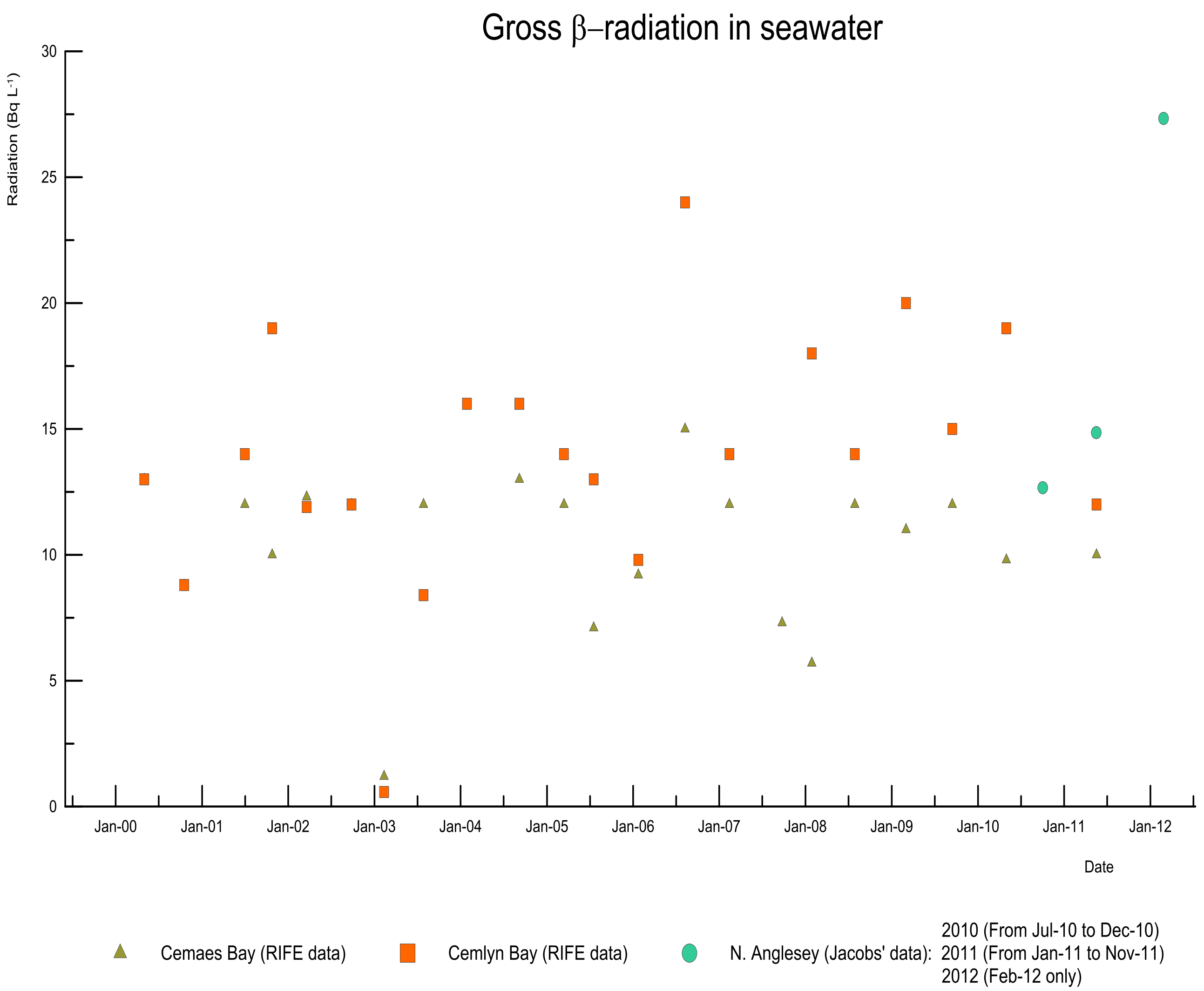


Figure 3.10 : Gross β-radiation detected in water samples collected from the sea around Wylfa Head. RIFE data were collected twice a year. All data collected by Jacobs have been annually averaged. It must be noted that in 2012 radiation was analysed in February only, therefore data reported for 2012 do not represent the annual average.

3.4 Discussion

All physico-chemical data recorded from May 2010 to November 2014, including vertical water column profiles, indicated no evidence of a permanent thermocline, halocline or seasonal stratification of the water body along the north Anglesey coast. Although all values recorded indicate a well-mixed water body, a weak thermal stratification and a very weak halocline were occasionally observed at different sites.

In some surveys, temperatures above ambient were observed at sites WQ2, WQ6 and WQ7 (see vertical profiles in Appendix A). Also, it must be noted that most of the weak thermal stratifications occasionally observed were found at these sites. These thermal anomalies are suspected to have been a localised short-term effect from the existing CW discharge as they were not observed at any other sites or commonly observed at these sites.

Due to similarity between sites in physico-chemical properties within the water column (temperature and salinity vertical profiles) and to the absence of permanent stratification within the area monitored, for data analysis purposes, the survey area was considered as one single water body. Monthly concentrations for this water body were calculated as the arithmetic mean of all samples collected in that month. Even though this is a valid approach, it has an implicit limitation, the direct dependence on the number of samples collected each month.

Therefore, due to the change in number of samples collected from year to year, the monthly concentration calculated for some months might have not fully reflected the mean concentration expected for the survey area as a whole. For instance, monthly concentrations (for some determinands or some months) calculated for the water body could have been based on a different number of samples (see Section 3.3.2 for more details).

Dissolved oxygen data recorded each month indicated high dissolved oxygen standards according to the WFD classification. All vertical profiles followed the same pattern: high dissolved oxygen at surface and a decreasing level of saturation with depth. In some months the highest levels of saturation were found at approximately 5 - 10 m depth. This was probably owing to the phytoplankton maximum abundance being located at that depth rather than the surface, and possibly excess primary production at these depths. Dissolved oxygen concentrations were higher during the winter months, when the water temperature is lower.

TSS reported by the laboratory and turbidity data collected with the multiparameter sonde indicated clear water between May 2010 and August 2012 (TSS <10 mg L^{-1}) along the north Anglesey coast and intermediate turbid in 2014 (between February and May, and during November). TSS annual averages were 4.6 to 7.0 mg L^{-1} between 2010 and 2012, and 13.0 mg L^{-1} in 2014. TSS was not monitored in 2013. Monthly averages for turbidity were always recorded below 10 NTU (between May 2010 and October 2012). Turbidity was not monitored after October 2012.

Average concentrations of dissolved inorganic nitrogen (calculated from dissolved oxidised nitrogen and ammoniacal nitrogen) between November and February inclusive indicated high dissolved inorganic nitrogen standard (<12 µmoles L^{-1}) under the WFD classification in 2010-11 and 2011-12. From 2012 onwards no survey was carried out between November and January, therefore dissolved inorganic nitrogen standard for 2012 - 2013 or 2013 - 2014 cannot be inferred.

The water body along the north Anglesey coast had good chemical status between May 2010 and November 2014. The good chemical status is based on annual average, monthly averages and maximum concentrations reported for priority substances, specific and other pollutants covered under the WFD and Priority Substance Directive.

All physico-chemical parameters, including cations and anions, analysed by the laboratory were reported at expected concentrations, with values typical of seawater. Nutrient concentrations were found to be low and at comparable concentrations throughout the duration of the baseline monitoring programme. These data indicated no nutrient enrichment in the area surveyed. The majority of organic compounds (TPHs and PAHs, PCBs, VOCs, phenols and CBPs) analysed were reported as below their MRV or LoD and compounds with levels above this value were found in very low concentrations (close to MRV or LoD). Most metals analysed at the laboratory were reported at low levels with some below MRV.

No AA-EQSs were exceeded during the baseline monitoring programme. Mercury was the only substance exceeding the MAC-EQS during 2010. The average concentration reported in October 2010 was 0.091 µg L^{-1} (MAC-EQS = 0.07 µg L^{-1}). It should be noted that the statutory mercury EQS in England and Wales has been set as 20 µg kg^{-1} of prey tissue (calculated from biota samples) and is not based on levels in water.

Similarly, when comparing all baseline survey results reported between May 2010 and November 2014 with the AA-EQS and MAC-EQS adopted in 22 December 2015, no AA-EQSs were exceeded and the only exceedance to the MAC-EQSs was mercury in October 2010.

NRW routinely monitored the water quality in North Anglesey as part of their coastal water monitoring programme. The only sampling point available in the area is Middle Mouse (sampling point code 25487 and National baseline site number 163), situated approximately 2 km offshore from Llanbadrig, north coast of Anglesey. The chemical data provided by NRW for this site (from January 1998 to April 2012) show a similar correlation when compared with the equivalent data obtained during these baseline surveys, with many concentrations reported as less than the MRV or marginally above this value.

In addition, the water temperatures recorded in the survey area throughout the baseline monitoring programme were compared with long-term data available from Cefas. Cefas had three temperature loggers moored in north Anglesey between 1966 and 2008 at different locations; one at Wylfa head, one in Amlwch (approximately 10.5

km east from the proposed power station) and one in Moelfre (east Anglesey, approximately 8.5 km south from the north Anglesey coastline). Water temperature monthly variations recorded by Jacobs between 2010 and 2014 are within the same range and comparable with the temperatures recorded by Cefas at these three locations (see Figure 3.11)

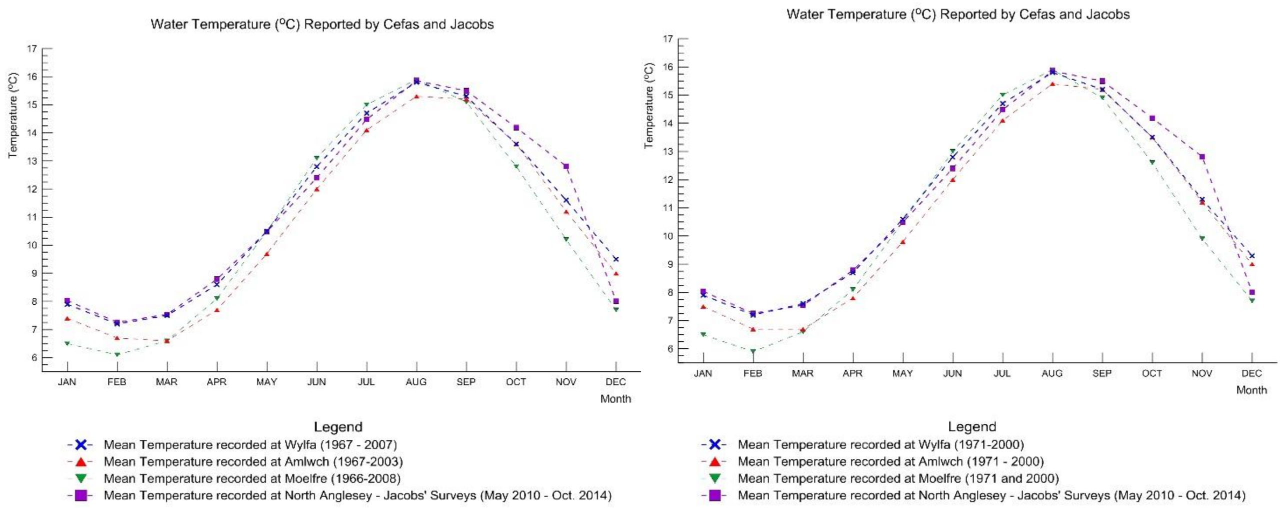


Figure 3.11 : Water temperature monthly means recorded by Cefas and Jacobs. The right hand side figure shows the mean values from all data available, while the left hand side figure shows Cefas data between 1971 and 2000 as well as Jacobs data collected during the baseline monitoring programme.

RIFE survey data for 2000 - 2011 for seawater sampled in Cemaes Bay and Cemlyn Bay were provided by the Environment Agency. Data collected as part of this baseline monitoring programme (between July 2010 and February 2012) can be compared with the RIFE data and can also be placed in the context of a longer-term monitoring programme (Figure 3.10, Section 3.3.2.8). In general, levels of β radiation detected in most samples collected through the monitoring programme are comparable with the RIFE data (between <5 Bq L^{-1} and 24 Bq L^{-1}), with the exception of November 2010 and February 2012, where high levels of radiation were reported in a few samples.

As many of the radiation levels were below the LoD it was not possible to detect whether radioactivity levels in the waters for the naturally occurring radioisotopes were above natural background levels. It was also not possible to identify whether the artificially created radioisotopes detected in the area are derived from the Existing Power Station. It is widely recognised that data for artificial radionuclides in and around the Irish Sea are strongly influenced and elevated by concentrations derived from discharges at Sellafield, which can all but mask locally derived activity. As the RIFE-16 and RIFE 17 reports (Cefas, 2011; 2012) state “the data for artificial radionuclides related to the Irish Sea continue to reflect the distant effects of Sellafield discharges”.

4. Water Quality under Non-operational Conditions

4.1 Introduction

The Existing Power Station ceased power generation on 30 December 2015. Following shutdown of the reactor, the main seawater cooling pumps remained active during de-fuelling activities to facilitate cooling of the heat exchangers and the boiler, although during this period the temperature differential between the intake and outfall was negligible.

This presented an opportunity to compare the water quality in the adjacent water body during operational and non-operational conditions, allowing a better understanding of any potential impacts from operation of the station. Two additional water quality surveys were carried out in December 2015 and February 2016 with the aim of assessing water quality during non-operational conditions and to evidence the validity of the data collected in previous years. This section presents the results of these two additional surveys and compares the data with that reported for the baseline monitoring programme (Section 3).

Although the first survey was originally programmed for the beginning of November 2015, persistent bad weather conditions delayed the survey until mid-December (15 December 2015). The second survey was carried out on 11 February 2016.

Eight sites were monitored, six of them (WQ2, WQ4, WQ6, WQ7, WQ8 and WQ9) as per the 2014 monitoring programme (Section 3.2.2 and Figure 2.1

Figure 2.1) and two additional sites (OF1 and OF2) close to the existing outfall structure (Figure 4.1). WQ8, WQ9 and the additional two sites were only monitored for physico-chemical parameters.

4.2 Method

Survey methodology, instrumentation and sampling technique were consistent with previous work. Please refer to Section 3.2 for further information regarding sampling methodology.

All of the physico-chemical parameters, and chemical and biochemical determinands monitored were the same as those monitored during the 2014 programme (February 2014 onward). Please refer to Sections 3.2.1, 3.2.1.2 and 3.2.2 for the full list of parameters monitored.

4.2.1 Legislative Standards Update

Please refer to Section 3.2.4.2 for a full list of the legislation and standards that apply.

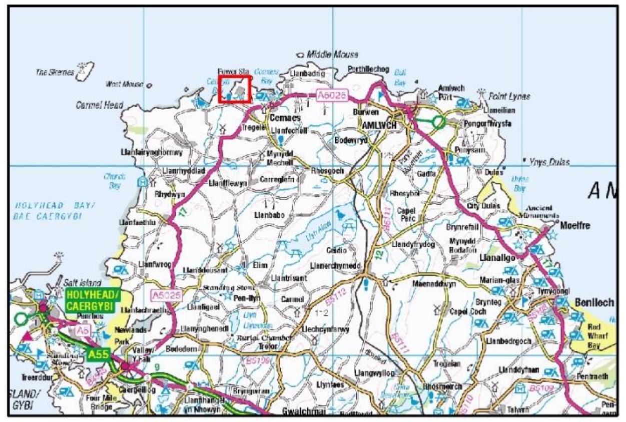
In August 2013 the EC adopted and published a Directive (2013/39/EU) which amends Directives 2000/60/EC (WFD) and 2008/108/EC (Priority Substance Directive). The new Directive lays down EQSs for an additional 12 substances (45 substances in total are now included, including priority substances and certain other pollutants).

In Wales '*The Water Environment (Water Framework Directive) (England and Wales) (Amendment) Regulation 2015 (S.I. 2015 No. 1623*)' came into force on 14 September 2015. Also, '*The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015*' in connection with the implementation of the '*Water Framework Directive (2000/60/EC)*', the '*Priority Substances Directive (2008/105/EC)*' and the *revised Priority Substance Directive (2013/39/EU)* partially came into force on 14 September 2015 and the revised EQSs were adopted on 22 December 2015. Where applicable, results have been compared to the new Marine Environmental Quality Standards (as per Directions 2015) as well as previous Directions (2010).

FIGURE 4-1

Legend

- Wylfa Newydd Development Area
- Water quality baseline sampling sites
- Additional water quality sampling sites



Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
0	DEC 17	Initial Issue	VG	HY	RW	RB

JACOBS
Kenneth Dibben House, Enterprise Road, Southampton, SO16 7NS
Tel: +44(0)2380111250 Fax: +44(0)2380111251

Client
HORIZON NUCLEAR POWER

Project
WYLFA NEWYDD PROJECT
WATER QUALITY AND PLANKTON REPORT

Drawing Title
ADDITIONAL WATER QUALITY SITES
NEAR THE EXISTING OUTFALL

Drawing Status

Scale @ A3	1:5,000	DO NOT SCALE
Jacobs No.	60PO8099	
Client No.		
Drawing No.	60PO8007_AQE_REP_004_04_01	

4.3 Results

4.3.1 Physico-Chemical Parameters

All vertical profiles recorded during the December 2015 survey and during the February 2016 survey can be found in Appendix E. For consistency purposes, two sets of vertical profiles were produced (see Appendix A). The first set includes all sites in the previous year's monitoring programme (WQ2, WQ4, WQ6, WQ7, WQ8 and WQ9). The second set includes the vertical profiles recorded at the two additional sites (OF1 and OF2) as well as sites WQ2, WQ4 and WQ6. The latter three sites were included in the second set to add context to the profiles recorded at the additional sites (see Figure 4.1).

For comparison purposes, 'survey area' includes only those WQ sites previously monitored (WQ2, WQ4, WQ6, WQ7, WQ8 and WQ9), and excludes both of the additional sites (OF1 and OF2).

4.3.1.1 Temperature

4.3.1.1.1 December 2015

Water temperature recorded in December 2015 ranged from 10.73°C to 11.12°C, with the mean value for the survey area reported as 10.85°C. The mean temperature recorded at each site was found to be comparable (between 10.75°C and 10.89°C). Water temperature was very stable through the water column at sites WQ2, WQ4, WQ6 and WQ7, with a vertical variation of 0.03°C or lower. The vertical variation at site WQ8 was 0.13°C, but no stratification was evident. At site WQ9 a degree of stratification was observed. The mean temperature for the surface layer (extending from the surface to approximately 5.6 m depth) was 11.00°C, while the mean temperature of the deep water layer (from 7 m to seabed) was 10.77°C. The stratification observed at site WQ9 may be a result of the Existing Power Station discharge.

Water temperatures recorded at the two additional sites (OF1 and OF2) close to the existing outfall (Figure 4.1) were clearly affected by the discharge. Temperatures recorded at site OF1 (approximately 50 m away from the outfall) ranged between 11.00°C (at depths between 8.6 m and the seabed (9.4 m)) and 15.22°C (at 0.95 m below the surface). A strong thermocline was observed at site OF1 at 4.4 m depth. Temperatures recorded below this depth were approximately 2.5°C lower than the surface layer. Water temperature recorded between 4.4 m and 8.6 m varied between 11.05°C and 13.58°C. Temperatures recorded at site OF2 (approximately 160 m away from the outfall) ranged between 10.81°C (near the seabed) and 11.57°C (0.13 m below the surface). The mean value recorded at this site was 11.12°C. No clear stratification was evident at this site. The water temperature decreased progressively from the surface to approximately 12 m. Temperatures recorded between a depth of 12 m and the seabed (18.5 m) were very stable with the mean value of 11.82°C.

4.3.1.1.2 February 2016

Water temperature recorded within the survey area in February 2016 ranged from 8.50°C to 8.69°C, with a mean value of 8.56°C. Vertical profiles at all sites showed very stable values through the water column with a vertical variation of 0.04°C or less. Water temperature was very similar across all sites, except at site WQ4. The mean value recorded at each site (excluding site WQ4) ranged between 8.51°C and 8.53°C. The water temperature recorded at site WQ4 was found to be 0.16°C higher compared with the rest of the sites. If site WQ4 is excluded, the mean value recorded for sites WQ2-WQ9 would be 8.52°C. The mean value recorded at site WQ4 was 8.68°C.

The water temperature recorded at the two additional sites (OF1 and OF2) was also found to be very stable through the water column. The mean values recorded at these two sites were very comparable with the mean value recorded elsewhere within the survey area at 8.57 °C and 8.56 °C, respectively.

4.3.1.2 Salinity

4.3.1.2.1 December 2015

Salinity values recorded at all sites in the survey area (except at site WQ4), were found to be very stable through the water column and between sites, with values recorded between 33.98 and 34.07. Values recorded at site WQ4 were found to be slightly elevated in comparison to the rest of the sites (between 34.09 and 34.11). The mean value recorded within the survey area was 34.05. No stratification was observed at any sites.

Salinity values recorded at site OF1 (approximately 50 m away from the outfall) ranged between 33.72 and 34.44, with a mean of 34.01. Salinity values recorded at site OF2 (approximately 160 m away from the outfall) ranged between 34.00 and 34.11, with a mean of 34.04. Mean values at both sites were similar to the mean value reported for the wider survey area.

4.3.1.2.2 February 2016

Salinity values recorded in February 2016 at all sites in the survey area were found to be very stable through the water column, with a vertical variation of 0.10 or less. Salinity values ranged between 34.14 and 34.30, with a mean of 34.22. Sites WQ7 and WQ9 (closest to Cemlyn Lagoon) recorded the lowest salinity, with mean values recorded as 34.20 and 34.19 respectively.

Salinity values recorded at the additional sites (OF1 and OF2) were also found to be stable through the water column, although the mean value recorded at these two sites, was lower (34.14 and 34.17 respectively).

4.3.1.3 Dissolved Oxygen

4.3.1.3.1 December 2015

DO saturation levels within the survey area ranged between 97.0% and 125.1% (both values recorded at site WQ4, at the surface and near the seabed respectively). The mean value recorded at all sites and depths was 109.3%. DO concentrations ranged between 8.63 mg L^{-1} (recorded at sites WQ4 and WQ8 at surface) and 11.13 mg L^{-1} (recorded at site WQ4 near the seabed). The mean value recorded at all sites and depths was 9.74 mg L^{-1}. All results indicate well oxygenated waters. Vertical profiles at all sites followed a similar pattern with lower DO values near the surface (between 97.0% and 98.7% and between 8.63 mg L^{-1} and 8.80 mg L^{-1}), with progressively increasing values towards the seabed (due to the pressure effect).

DO values recorded at the two additional sites (OF1 and OF2) were found to be comparable with all other sites. At site OF1, saturation levels were 101.2% and concentration levels 8.26 mg L^{-1}. The differences recorded at this site compared with the other sites (including OF2) are thought to be attributable to the outfall and water turbulence generated.

4.3.1.3.2 February 2016

DO saturation levels recorded in February 2016 ranged between 94.1 % (recorded at site WQ7 at surface) and 128.0% (recorded at site WQ4, between approximately 34 m and 36 m depth). The mean value recorded at all sites and depths was found to be 109.4%. DO concentration levels ranged between 8.83 mg L^{-1} and 11.95 mg L^{-1} (also recorded at sites WQ7 and WQ4 at similar depths as the saturation levels). The mean DO concentration level, recorded at all sites and depths, was 10.24 mg L^{-1}. Vertical profiles at all sites followed a similar pattern and were comparable between sites, except at site WQ4, where levels were slightly higher. DO values at the surface at all sites, except at WQ4, were very similar (between 94.1% and 95.9% and between 8.83 mg L^{-1} and 8.99 mg L^{-1}). At site WQ4 DO at the surface was found to be 98.3% and 9.18 mg L^{-1}.

DO values recorded at the two additional sites (OF1 and OF2) were similar to all other sites (except site WQ4). DO values at these two sites range from 94.8% to 108.7% and 8.87 mg L^{-1} and 10.19 mg L^{-1}.

4.3.1.4 pH

4.3.1.4.1 December 2015

pH values recorded at all sites, including the two additional sites (OF1 and OF2) were found to be very stable through the water column and between sites. Values range between 8.30 and 8.37.

4.3.1.4.2 February 2016

pH values recorded at all sites, including the additional sites (OF1 and OF2) were found to be comparable, ranging between 8.13 and 8.17.

4.3.1.5 Oxidation Reduction Potential or Redox

4.3.1.5.1 December 2015

ORP values recorded at all sites, including the two additional sites (OF1 and OF2), were found to be stable through the water column. Vertical profiles at all sites showed very little variation with depth. The vertical variations recorded at each site were found to be less than 10 mV. ORP values recorded within the survey area (excluding the additional sites OF1 and OF2) ranged between 236.5 mV (recorded at site WQ2 near the seabed) and 258.5 mV (recorded at site WQ4 at surface). Including the two additional sites, the range was between 236.5 mV and 261.7 mV.

ORP values at site OF2 were similar to those recorded at all other sites. Values recorded at OF1 may have been affected by the discharge as the vertical profile differed noticeably from the other sites. The highest value recorded was 261.7 mV at a depth of approximately 5 m below the surface rather than at surface (found at all other sites).

4.3.1.5.2 February 2016

ORP values recorded at all sites, including the additional sites (OF1 and OF2), during the February 2016 survey ranged between 205.9 mV and 287.7 mV. ORP values were found to be very stable through the water column at all sites, with a vertical variation of 3.5 mV or less (except at site WQ2 where the vertical variation recorded was 12.8 mV.

4.3.2 Laboratory Analysis Results

As the survey area can be considered as one water body, the arithmetic mean of all samples collected can be used to represent the value of the water body (see Section 3.3.2 for more information).

4.3.2.1 Physico-Chemical Determinands

Mean physico-chemical results reported by the laboratory can be found in Appendix F.

4.3.2.1.1 Organic Carbon (TOC and DOC)

Mean TOC value within the survey area was reported as <1 mg L^{-1} in December 2015 and February 2016.

Mean DOC value reported within the survey area was 0.55 mg L^{-1} in December 2015 and 0.70 mg L^{-1} in February 2016.

4.3.2.1.2 Total Suspended Solids (TSS)

TSS in December 2015 was reported between 12.5 mg L^{-1} and 21.4 mg L^{-1}, while in February 2016 values were reported between 12.2 mg L^{-1} and 20 mg L^{-1}. The mean value reported in December 2015 was 16.4 mg L^{-1}, while in February 2016 the mean value was 16.6 mg L^{-1}.

4.3.2.2 Cations and Anions

All concentrations measured in December 2015 and February 2016 (Appendix F), were reported within the expected values for coastal waters (Turekian, 1976)., with no significant variations between sites and in line with concentrations reported during the baseline monitoring programme (Section 3).

4.3.2.3 Nutrients

Mean nitrogen (as N) concentration reported was 0.210 mg L^{-1} in December 2015 and 0.189 mg L^{-1} in February 2016. Total organic nitrogen (as N), dissolved inorganic nitrogen (as N), ammoniacal nitrogen (as N) and Kjeldahl nitrogen (as N) were all reported as below MRV for samples taken in December 2015 and February 2016. Total oxidised nitrogen (as N) was reported as below MRV in December 2015 but marginally above the MRV in February 2016 (mean value reported was 0.103 mg L^{-1} and the current MRV is 0.100 mg L^{-1}).

Un-ionised ammonia concentrations (calculated from temperature, pH and ammoniacal nitrogen) were reported well below the relevant EQS (21 μg L^{-1}). The mean value reported in December 2015 was 0.782 μg L^{-1} and in February 2016 was 0.448 μg L^{-1}.

Nitrite and nitrate were also reported as below the MRV in all samples collected in December 2015 and February 2016.

Orthophosphate (also known as soluble reactive phosphorus) mean concentrations were 0.036 mg L^{-1} in December 2015 and 0.018 mg L^{-1} in February 2016. Mean silicate concentrations were reported as 0.30 mg L^{-1} in December 2015 and 0.36 mg L^{-1} in February 2016.

All results can be found in Appendix F.

4.3.2.4 Metals

All metals were reported as below the relevant EQSs. Concentrations for boron, nickel, copper, zinc, arsenic and lead were all found within the expected values for coastal waters (Turekian, 1976). Vanadium, chromium, manganese, iron, cobalt, selenium, cadmium, tin and mercury were found below MRV in all samples (Appendix F).

4.3.2.5 Organic Compounds

4.3.2.5.1 Total Petroleum Hydrocarbons

Total petroleum hydrocarbons (TPH) were reported as below the MRV (0.2 mg L^{-1}) in all samples collected in December 2015 and February 2016.

4.3.2.5.2 Polycyclic Aromatic Hydrocarbons and Polychlorinated Biphenyls

Concentrations of all polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) monitored were reported as below the MRV (0.001 µg L^{-1} or 0.002 µg L^{-1} or 0.01 µg L^{-1} depending on the compound) in all samples collected in December 2015 and February 2016.

4.3.2.5.3 Volatile Organic Compounds

All Volatile Organic Compounds (VOCs) monitored in December 2015 and February 2016 were reported as below the MRV with no exceptions. The MRV was set by the laboratory as 0.1 µg L^{-1}, 0.2 µg L^{-1} or 0.5 µg L^{-1} depending on the particular compound.

4.3.2.5.4 Phenols

All phenolic compounds monitored were reported as below the MRV (<0.02 µg L^{-1}), except for 3,5-dimethylphenol and phenol. 3,5-dimethylphenol was reported above the MRV (0.113 µg L^{-1}) in one sample in February 2016 only. The mean value for the survey area remained below the MRV. Phenol was detected in two samples in December 2015 and another two samples in February 2016. All these samples were reported marginally above the MRV (0.0725 µg L^{-1} or lower). The mean value for the survey area was reported as below the MRV (0.05 µg L^{-1}) in both December and February.

4.3.2.6 Cyanide

All results were reported below their MRV (0.5 mg L^{-1} for total cyanide as CN and 0.005 mg L^{-1} for free cyanide as CN).

4.4 Discussion

The water temperature recorded within the survey area in December 2015 was considered higher than expected (approximately 2°C higher). In addition, the water temperature recorded in February 2016 was between approximately 1°C and 1.5°C higher than water temperatures recorded in previous years within the same area. According to the Met Office (2016) the air temperature recorded in December 2015 for the region was approximately 4.3°C higher than the mean temperature recorded in December between 1981 and 2010. In January 2016, the air temperature recorded in north Wales was approximately 0.3°C higher than the mean temperature for the same time series (1981 - 2010). The overall air temperature recorded in winter 2015 - 2016 was found to be 2.0°C higher than the mean temperature recorded in winter between 1981 and 2010 (Met Office, 2016). The elevated seasonal air temperatures may have accounted for the higher than expected seawater temperatures recorded during the surveys.

In December 2015, the water column was found to be stratified at site WQ9 (approximately 1 km from the outfall) and at one of the additional sites (OF1, the closest to the outfall). This clearly indicates that the thermal impact generated by the outfall discharge is mostly localised to the vicinity of the structure and the thermal discharge dissipates relatively quickly and in a short distance. No other site was found stratified in December or February 2016.

Salinity values recorded at all sites in December 2015 and February 2016 were in line with previous values recorded in the study area. No stratification or halocline was observed at any of the sites, however very unstable values were recorded within the water column at one of the additional sites monitored in December 2015 (OF1), possibly due to the turbulent water conditions generated by the discharge. Salinity values at this site were highly variable through the water column, and it is suggested that the turbulence produced by the discharge could be affecting readings.

DO data recorded at each site in December 2015 and February 2016 indicate high DO levels when compared to WFD standards. DO levels (% saturation and mg L^{-1}) at the surface and through the water column at all sites were very similar. All DO data recorded in December 2015 and February 2016 are in line with values reported during the baseline surveys (see Section 3.3.1.3).

TSS reported by the laboratory in December 2015 and February 2016 were found at similar levels (mean values of 16.4 mg L^{-1} and 16.6 mg L^{-1} respectively) and just above the WFD threshold value for clear waters (<10 mg L^{-1}). In line with WFD classification and the TSS values reported, the water body along the north Anglesey coast could be classified as intermediately turbid during December 2015 and February 2016. The water body in this area has previously been classified as clear water, and it is suggested that the persistent stormy weather may have affected the level of suspended solids within the water column at the time of both surveys.

Total organic nitrogen, dissolved inorganic nitrogen, ammoniacal nitrogen and Kjeldahl nitrogen were all reported as below MRV in December 2015 and February 2016. All other nutrients (nitrate, nitrite, orthophosphate and silicate) were recorded at levels similar to those previously reported for the survey area.

The water body along the north Anglesey coast attained Good chemical status in both December 2015 and February 2016. This status is based on monthly averages and maximum concentrations reported for priority substances and other specific pollutants covered under the WFD and Priority Substance Directive. No differences, other than the seasonal variation, have been observed between the concentrations reported by the laboratory in December 2015 and February 2016 and those previously reported for the survey area.

All physico-chemical parameters, including cations and anions, analysed by the laboratory were reported at expected concentrations, with values typical of seawater and at comparable concentrations with those values previously reported for the survey area during the baseline monitoring programme (between May 2010 and November 2014).

The mean values reported for all organic compounds (TPHs and PAHs, PCBs, VOCs and phenols) analysed in December 2015 and February 2016, were below their MRVs. These results are in line with results reported during the baseline programme.

The data reported from the December 2015 and February 2016 surveys indicate that the water quality status along the north Anglesey coastline remains Good, in line with the data reported during the baseline monitoring programme (Section 3.4). The results validate the continued use of the baseline data collected between May 2010 and November 2014, but also indicate that the Existing Power Station's operations were having a negligible impact on the water quality of the adjacent water body. The water quality data collected in February 2016 (non-operational conditions) do not show any difference from that collected in December 2015 or during the baseline monitoring programme (May 2010 – November 2014), with the exception of water temperature close to the outfall area.

5. Water Quality at Holyhead North

5.1 Introduction

As part of the Wylfa Newydd Generating Station and Associated Development, it is assumed that planned excavation work within the area of Porth-y-pistyll will result in large volumes of dredged material requiring disposal at sea and the licensed disposal site Holyhead North (IS043) offers the best option.

In order to characterise the marine environment around the proposed disposal site at Holyhead North and gathering relevant information to support all required applications, an extended baseline survey was carried out within the area in October 2016 and December 2016. As part of this characterisation a single water quality survey was carried out on 31 October 2016. This section presents the results reported for this water quality survey.

Six sites were monitored for the water quality element (Figure 5.1). Four sites were strategically selected to cover the area where disposal can take place (Sites HHD_02, 08, 14 and 16) and two sites outside of this area (HHD_04 and 18).

5.2 Method

Survey methodology, instrumentation and sampling technique were consistent with the work carried out during the baseline monitoring programme. In order to increase the sampling resolution in the area, water samples for chemical and biochemical analysis were collected below the surface (1m depth) and at mid depth. The reader should refer to Section 3.2 for further information regarding sampling methodology.

The main physico-chemical parameters were measured *in situ* throughout the vertical water column, including temperature, conductivity, salinity, DO, pH and ORP.

The chemical and biochemical determinands monitored were the same as those monitored during the 2014 programme (February 2014 onward). However, most organic compounds were excluded from the list of determinands (PAHs, VOCs and phenols compounds). Please refer to Sections 3.2.1, 3.2.1.2 and 3.2.2 for the full list of parameters monitored.

5.3 Results

5.3.1 Physico-Chemical Parameters

All vertical profiles recorded at Holyhead Deep during the October 2016 survey can be found in Appendix G. A summary of the physico-chemical properties recorded *in situ* is presented below:

- Temperature within the survey area varied between 13.99°C and 14.08°C. The difference recoded within the vertical water column at each site was 0.05°C or lower.
- Conductivity values recorded within the survey area varied between 40.878 mS cm^{-2} and 41.091 mS cm^{-2}.
- Salinity values recorded within the survey area varied between 33.99 and 34.15. The difference recoded within the vertical water column at each site was 0.16 or lower.
- Dissolved oxygen (saturation) recoded within the survey area varied between 90.5% and 96.2%. The difference recoded within the vertical water column at each site was 5.7% or lower.
- Dissolved oxygen (concentration) recoded within the survey area varied between 7.54 mg L^{-1} and 8.01 mg L^{-1}. The difference recoded within the vertical water column at each site was 0.47 mg L^{-1} or lower.
- pH values recoded within the survey area varied between 8.18 and 8.23. The difference recoded within the vertical water column at each site was 0.03 or lower.

- ORP values recoded within the survey area varied between 291.3 mV and 325.7 mV. The difference recoded within the vertical water column at each site was 14.1 mV or lower.

5.3.2 Legislative Standards Updated

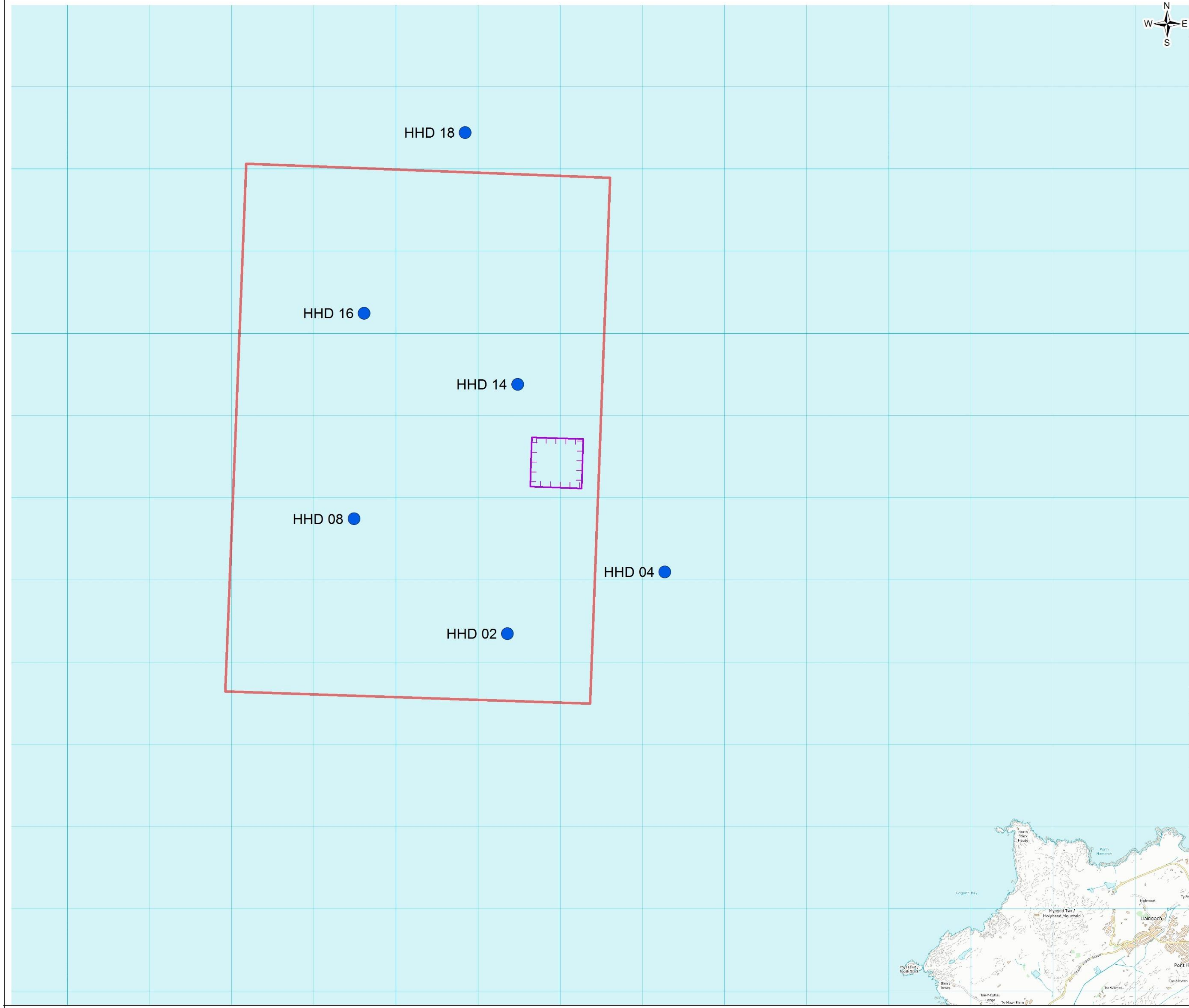
The reader should refer to Section 3.2.4.2 for a full list of the legislation and standards that apply.

In Wales '*The Water Environment (Water Framework Directive) (England and Wales) (Amendment) Regulation 2015 (S.I. 2015 No. 1623*)' came into force on 14 September 2015. Also, *'The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015*' in connection with the implementation of the *'Water Framework Directive (2000/60/EC)*', the '*Priority Substances Directive (2008/105/EC)*' and the *revised Priority Substance Directive (2013/39/EU)* partially came into force on 14 September 2015 and was adopted on 22 December 2015. Where applicable, results have been compared to the new Marine Environmental Quality Standards (as per Directions 2015).

FIGURE 5-1

Legend

- Disposal Site
- Rock disposal area
- Water quality survey sites



0 0.5 1 2 3 4 kilometres

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
0	DEC 17	Initial Issue	VG	HY	RW	RB

JACOBS
Kenneth Dibben House, Enterprise Road, Southampton, SO16 7NS
Tel: +44(0)2380111250 Fax: +44(0)2380111251

Client
HORIZON NUCLEAR POWER

Project
WYLFA NEWYDD PROJECT
WATER QUALITY AND PLANKTON REPORT

Drawing Title
WATER QUALITY SAMPLING SITES AROUND THE PROPOSED ROCK DISPOSAL AREA

Drawing Status

Scale @ A3	1:45,000	DO NOT SCALE
Jacobs No.	60PO8099	
Client No.		

Drawing No.
60PO8007_AQE_REP_004_05_01

5.3.3 Laboratory Analysis Results

Full results reported for this survey can be found in Appendix H and are summarise below.

5.3.3.1 Physico-Chemical Determinands

5.3.3.1.1 Organic Carbon, Total and Dissolved (TOC and DOC)

TOC concentrations were reported between 0.77 mg L^{-1} and 0.86 mg L^{-1}. The mean value reported within the survey area was 0.81 mg L^{-1}.

DOC concentrations were reported between 0.90 mg L^{-1} and 1.20 mg L^{-1}. The mean value reported from all samples was 1.06 mg L^{-1}.

5.3.3.1.2 Biological oxygen Demand (BOD)

BOD values were reported below the MRV (1.00 mg L^{-1}) in all samples except at site HHD_08 at surfaces, where it was reported marginally above (1.15 mg L^{-1})

5.3.3.1.3 Total Suspended Solids (TSS)

TSS for samples collected at surfaces ranged from <3.0 mg L^{-1} and 5.2 mg L^{-1}, while samples collected at mid depth ranged from 3.9 mg L^{-1} and 14.7mg L^{-1}. The mean value reported at surface was 3.6 mg L^{-1} while the mean value reported at mid depth was 7.5 mg L^{-1}. The mean value reported within the survey area (considering all samples collected) was 5.5mg L^{-1}.

5.3.3.2 Cations and Anions

All concentrations reported around Holyhead Deep were found within the expected values for coastal waters (Turekian, 1976), with no significant variations between sites and in line with concentrations reported during the baseline monitoring programme (Section 3).

5.3.3.3 Nutrients

Most of the Nitrogen and nutrients concentrations reported were found below the respective MRW. A summary of the concentration reported is presented below:

- The mean nitrogen (as N) concentration reported was 0.183mg L^{-1}.
- Total organic nitrogen (as N), inorganic nitrogen (as N), ammoniacal nitrogen (as N), Kjeldahl nitrogen (as N), nitrite (as N) and nitrate (as N) were all reported as below MRV.
- Total Oxidised nitrogen (as N) was reported as below MRV (0.0040 mg L^{-1}) in all samples except for one, reported marginally above (0.0056 mg L^{-1})
- Un-ionised ammonia concentrations (calculated from temperature, pH and ammoniacal nitrogen) were reported well below the relevant EQS (21 μg L^{-1}). The mean concertation reported in Holyhead Deep area was <0.785 μg L^{-1}.
- Orthophosphate (as P) was reported as either 0.014 mg L^{-1} or 0.015 mg L^{-1} in all samples. The mean value reported was 0.015 mg L^{-1}.
- Silicate concentrations (as SiO_2) in all samples was reported as either <0.200 mg L^{-1} or as 0.200 mg L^{-1}. The mean value remained below MRV.

5.3.3.4 Metals

All metals concentrations reported for the area were found below the relevant EQSs. However, zinc was reported between 1.37 μg L^{-1} and 12.80μg L^{-1}. The mean concentration reported within the survey area was

4.32 μg L^{-1}, below the current EQS (7.9 μg L^{-1}). If the sample reported above the EQS (collected at site HHD_18 at 34.5 m depth) is excluded, the highest concentration reported would have been 6.05 μg L^{-1} and the mean concentrations would have been 3.55 μg L^{-1}.

Concentrations for boron, copper, zinc, arsenic and lead were all found within the expected values for coastal waters (Turekian, 1976). Nickel was reported marginally above the MRV in four samples, however, the mean value reported remained below the MRV. Vanadium, chromium, manganese, iron, cobalt, selenium, cadmium, tin and mercury were all found below MRV in all samples.

5.3.3.5 Organic Compounds

Total petroleum hydrocarbons (TPH) and di-2-ethylhexyl phthalate (DEHP) were reported as below the MRV (0.2 mg L^{-1}) in all samples collected.

5.3.3.6 Cyanide

All results were reported below their MRV (0.5 mg L^{-1} for total cyanide as CN and 0.005 mg L^{-1} for free cyanide as CN).

5.4 Discussion

All physico-chemical properties, as well as cations, anions and metals concentrations reported, are considered normal and in line with expected values from coastal water (Turekian, 1976).

Conservative properties (temperature and salinity) were found very stable throughout the water column and through the survey area, indicating the absence of permanent stratification within the area, a very well mixed water body and a unique mass of water.

DO values recorded within the vertical water column at all sites are ‘High’ according with current WFD classification (>5.74 mg L^{-1}).

The mean suspended solids (as total) reported in all samples classified the areas as clear water under WFD criteria used to identified the type of waters.

Most nutrient concentrations were found below the laboratory’s minimum reportable value (MRV) or marginally above this value.

All results reported by the laboratory were compared with environmental quality standards (EQS) when applicable. No exceedance from annual averages or maximum allowable concentrations values were reported for any of the determinands analysed. Moreover, all concentrations reported by the laboratory are in line with ‘Good’ chemical status defined by the WFD and consistent with other coastal water with absence of pollution substances.

Zinc concentration was reported above the relevant long-term EQS in one sample, collected at site HHD_18 at 34.5m. It must be noted the zinc EQS (6.8 μg L^{-1} + 1.1 μg L^{-1} background concentration) refer to the annual mean. No maximum allowable concentration has been established of this pollutant. The mean value recorded in all samples (4.32 μg L^{-1}) was still well below the mentioned EQS.

6. Water Quality at Cemlyn Lagoon

6.1 Introduction

During the construction phase of the Wylfa Newydd Generating Station and Associated Development, it is anticipated that several discharges (e.g. dewatering and sewage) will take place. Although direct discharge to Cemlyn lagoon or Cemlyn stream will not take place, some of the surface water from Cemlyn stream might be diverted (up to 10% of the total volume running) to support the settlement and treatment operations of effluents produced during construction.

In order to understand and assess the current water quality and physico-chemical conditions in Cemlyn lagoon, four sites (see Figure 6.1 and Table 6.1) were monitored since October 2017. The location of these four sites corresponds to the sites previously monitored for total suspended solids between January 2016 and April 2016 and although there is an ongoing monitoring programme in place, laboratory results were only available for October and November 2017 at the time this report was finalised. Results for total suspended solids between January 2016 and April 2016 are also presented in this section.

It must be noted that Cemlyn lagoon is a designated SSSI and is currently part of the Anglesey Heritage Coast and the Isle of Anglesey Area of Outstanding Natural Beauty.

Table 6.1 : Water quality sampling locations in Cemlyn lagoon.

Site	Target Location
ST1	53.407557, -4.508179
ST2	53.409160, -4.509989
ST3	53.409309, -4.514799
ST4	53.411042, -4.513330

6.2 Method

Water samples were collected at each site using a sampling bucket. When the water depth allowed a subsurface sample was obtained, however the majority of samples were collected from the surface as generally water depth in the areas surveyed were less than 0.5 m. The main physico-chemical parameters (temperature, salinity, conductivity, dissolved oxygen and pH) were measured *in situ* using a handheld YSI® multimeter.

The instrument used to measure all physico-chemical parameters was calibrated and checked following a similar protocol to that described in Section 3.2.3.

The chemical and biochemical determinands monitored were the same as those monitored during the 2014 programme (February 2014 onwards). The reader should refer to Sections 3.2.1, 3.2.1.2 and 3.2.2 for the full list of parameters monitored.

6.2.1 Legislative Standards

The reader should refer to Section 3.2.4.2 for a full list of the legislation and standards that apply. The current EQSs applied to surface waters in Wales are summarised by '*The Water Environment (Water Framework Directive) (England and Wales) (Amendment) Regulation 2015 (S.I. 2015 No. 1623)*' and '*The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015*'.

Contains public sector information licensed under the Open Government Licence v3.0

FIGURE 6-1

Legend

Wylfa Newydd Development

Water quality sampling sites

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
0	DEC 17	Initial Issue	VG	HY	RW	RB

JACOBS

Kenneth Dibben House, Enterprise Road, Southampton, SO16 7NS
Tel: +44(0)2380111250 Fax: +44(0)2380111251

Client

HORIZON
NUCLEAR POWER

Project

WYLFA NEWYDD PROJECT
WATER QUALITY AND PLANKTON REPORT

Drawing Title

WATER QUALITY SAMPLING SITES
IN CEMLYN LAGOON

Drawing Status

Scale @ A3	1:4,329	DO NOT SCALE
Jacobs No.	60PO8099	
Client No.		

Drawing No.

60PO8007_AQE_REP_004_06_01

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

6.3 Results

All results reported by the laboratory can be found in Appendix I.

6.3.1 Physico-Chemical parameters

A summary of the physico-chemical properties recorded *in situ* in Cemlyn lagoon can be found in Table 6.2 below.

Table 6.2 : Summary of physico-chemical parameters measured in Cemlyn lagoon.

Parameter (*in situ*)	Units	October 2017	November 2017	December 2017
Temperature of Water (mean value)	ºC	10.59	11.75	2.35
Salinity (mean value)	Unitless	23.12	23.05 (*)	16.05
Conductivity (mean value)	mS cm^{-1}	26.510	27.252 (*)	15.241
DO concentration (mean value)	mg L^{-1}	8.73	9.69	13.18
DO saturation (mean value)	%	90.7	101.1	107.4
pH (range)	n/a	7.89 - 8.16	8.22 - 8.29	7.62 - 8.22

(*) salinity and conductivity value from site ST1 (9.55 and 12.132 mS cm^{-1}) were not considered when calculating the mean value for the area in November because it was highly influenced by the freshwater inputs and considerably different than values recorded at all other sites within the lagoon.

6.3.2 Laboratory Analysis Results

Monthly mean values reported for the survey area can be found in Appendix I and are summarised below.

6.3.2.1 Physico-Chemical Determinands

6.3.2.1.1 Organic Carbon, Total and Dissolved (TOC and DOC)

Between October and November 2017:

- TOC concentrations were reported between 2.5 mg L^{-1} and 5.1 mg L^{-1}, while the mean value reported within the survey area was 3.74 mg L^{-1}.
- DOC concentrations were reported between 2.41 mg L^{-1} and 5.32 mg L^{-1}, while the mean value reported was 3.63 mg L^{-1}.

6.3.2.1.2 Biological Oxygen Demand (BOD)

BOD values reported in October 2017 ranged between 1.12 mg L^{-1} and 1.58 mg L^{-1}, while in November 2017 values ranged from <1.00 mg L^{-1} to 1.47 mg L^{-1}. The mean value reported for the survey area in October 2017 was 1.33 mg L^{-1} while the mean value reported in November 2017 remained below the MRV.

6.3.2.1.3 Total Suspended Solids (TSS)

TSS concentrations reported in October 2017 ranged from 5.7 mg L^{-1} to 17.1 mg L^{-1}, while concentrations reported in November 2017 ranged from 3.0 mg L^{-1} to 18.7 mg L^{-1}. The mean value reported for both months remained below 10 mg L^{-1} (clear/intermediate turbid boundary under WFD classification) with values reported as 9.4 mg L^{-1} and 7.8 mg L^{-1} for October 2017 and November 2017, respectively.

TSS concentrations reported between January 2016 and April 2016 are presented below in Table 6.3.

Table 6.3 : Suspended solids concentrations reported at Cemlyn lagoon between January and April 2016.

Suspended Solids (mg L^{-1})	ST1	ST2	ST3	ST4
27/01/2016	59	No sample (*)	293	201
29/02/2016	117	51.2	39.5	11.4
20/04/2016	13.3	61.3	41.5	49

(*) ST2 was not monitored on 27th January 2016 due to access restriction to the site.

6.3.2.2 Cations and Anions

All concentrations reported within Cemlyn lagoon were found within the expected values for saline waters (Turekian, 1976), with the exception of the sample collected at site ST1 in November 2017. This particular sample was heavily influenced by the freshwater inputs from Cemlyn stream and cations and anions concentrations were reported considerably lower compared to the other sites (matching the characteristic values of freshwater inputs). The mean concentrations reported for the survey area can be found in Table 6.4.

Table 6.4 : Mean cations and anions concentrations reported in Cemlyn lagoon.

Compound	*Units*	October 2017	November 2017 (*)
Bromide	mg L^{-1}	43.9	45.8*
Calcium, Dissolved	mg L^{-1}	290	276*
Potassium, Dissolved	mg L^{-1}	315	284*
Sodium, Dissolved	mg L^{-1}	6998	6940*
Sulphate, Dissolved as SO_4	mg L^{-1}	1860	1800*

(*) concentrations reported at site ST1 were excluded from the mean value due to the freshwater influences. Concentrations reported at this site were: Bromide 18.5 mg L^{-1}, dissolved calcium 13.9 mg L^{-1}, dissolved potassium 11mg L^{-1}, dissolved sodium 305mg L^{-1} and dissolved sulphate 75.8mg L^{-1}.

6.3.2.3 Nutrients

A summary of the nutrient concentrations reported in October and November 2017 is presented below:

- The mean nitrogen (as N) concentration reported in October 2017 was 0.981 mg L^{-1} with values ranging between 0.633 mg L^{-1} and 1.690 mg L^{-1}. The mean concentration reported in November 2017 was 1.205 mg L^{-1} with values ranging between 0.703 mg L^{-1} and 2.510 mg L^{-1}.
- The total organic nitrogen (as N) concentration reported in October 2017 ranged between <0.955 mg L^{-1} and <0.980 mg L^{-1}. Similarly, in November 2017, organic nitrogen concentrations ranged between <0.938 mg L^{-1} and <0.975 mg L^{-1}.
- Ammoniacal nitrogen (as N) in October 2017 was reported between <0.02 mg L^{-1} and 0.045 mg L^{-1}. The mean value in October was reported as 0.026 mg L^{-1}. In November 2017, the ammoniacal nitrogen ranged from 0.025 mg L^{-1} and 0.062 mg L^{-1} and the mean value was reported as 0.037 mg L^{-1}.
- Un-ionised ammonia (as N), which is calculated from temperature, pH and ammoniacal nitrogen were reported bellow the EQS (21 µg L^{-1}) in all samples. The maximum concentration reported between October and November 2017 was 2.11 µg L^{-1} (reported in November at site ST1).
- The dissolved inorganic nitrogen (as N) fraction reported in October 2017 ranged between <0.340 mg L^{-1} and 1.250 mg L^{-1}, while in November 2017 it ranged between 0.375 mg L^{-1} and 2.050 mg L^{-1}. In both months, the highest concentrations were reported at site ST1 while the lowest concentrations were reported at site ST4.
- Oxidised nitrogen (as N) was reported between 0.25 mg L^{-1} and 1.20 mg L^{-1} in October 2017 and between 0.35 mg L^{-1} and 1.99 mg L^{-1} in November 2017.
- Nitrite concentrations reported in October 2017 ranged from 0.0092 mg L^{-1} and 0.0136 mg L^{-1}, while concentrations reported in November 2017 ranged from 0.0094 mg L^{-1} and 0.0263 mg L^{-1}.

- Orthophosphate (as P) was reported between <0.01 mg L^{-1} and 0.019 mg L^{-1} in October 2017 and between <0.01 mg L^{-1} and 0.023 mg L^{-1} in November 2017. The mean value reported in both months was just above the MRV (0.011 mg L^{-1} for both months).
- Silicate concentrations (as SiO_2) was reported between 0.65 mg L^{-1} and 4.63 mg L^{-1} in October 2017 and between 0.5 mg L^{-1} and 5.74 mg L^{-1} in November 2017. The mean value reported was comparable in October and November 2017 (1.93 mg L^{-1} in October and 1.96 mg L^{-1} in November).

6.3.2.4 Metals

All metals concentrations reported between October and November 2017 in Cemlyn lagoon were found below the relevant EQSs. Moreover, a number of metals (selenium, cobalt, tin, cadmium, iron, vanadium and chromium and the dissolved fractions of mercury and iron) were reported below the laboratory MRV in all samples. Arsenic and mercury (total fraction) concentrations were also reported as below MRV with one exception for both metals. Arsenic was reported marginally above MRV in one sample (ST4) in October 2017 and mercury (total fraction) was reported marginally above MRV in one sample (ST2) in November 2017.

All other metal concentrations are summarised in Table 6.5 below:

Table 6.5 : Ranges of dissolved metals concentrations reported above MRV.

Dissolved metals (µg L^{-1})	EQS	October 2017	November 2017
Copper	3.76	0.600 - 0.816	0.947 - 1.240
Lead	1.3	<0.0400 - 0.0482	0.0575 - 0.0808
Nickel	8.6	0.607 - 0.904	0.518 - 0.826
Zinc	7.9	1.82 - 3.28	1.86 - 3.04
Boron	7000	2200 - 3780	<700 - 2970
Manganese	n/a	23.0 - 87.7	<20.0 - 33.2

6.3.2.5 Organic Compounds

The majority of organic compounds monitored between October and November 2017 (TPHs, PAHs, PCBs, VOCs and Phenols) were reported as below the MRV in all samples collected. However, three exceptions were reported:

- 4-Methylphenol, also known as p-cresol, was reported marginally above MRV at site ST1 in October (0.0314 µg L^{-1}) and November (0.0298 µg L^{-1}).
- Phenol was reported in all samples, between 0.104 µg L^{-1} and 0.307 µg L^{-1} in October 2017 and between 0.0812 µg L^{-1} and 0.196 µg L^{-1} in November 2017.
- Di-2-ethylhexyl phthalate (DEHP) was reported marginally above MRV at site ST2 (0.282 µg L^{-1}) in November 2017.

A full list of organic compounds reported as below MRV can be found in Table I.7 in Appendix I.

6.3.2.6 Cyanide

All results were reported below their MRV for total cyanide as CN and for free cyanide as CN.

6.4 Discussion

Temperature values recorded within Cemlyn lagoon between October and December 2017 were found within the expected values when compared with data gathered by the former CCW between August 2006 and December 2011.

Similarly, salinity values recorded between October and December 2017 are also comparable with previous studies undertaken within the lagoon (Jones, 1978; Bamber *et al*., 2000, 2001; Epworth and Haycock, 2006 and Nikitik, 2007). When looking at individual stations, the lowest salinity was always recorded at ST1 (the closest to Cemlyn stream), where the highest input of freshwater occurs. All other stations recorded comparable values between them.

DO values recorded at all sites within the lagoon are 'High' according with current WFD classification (7.97 mg L^{-1} or higher). The mean DO concentration recorded for the lagoon was lowest in October 2017 (8.73 mg L^{-1}) and increased in November and December 2017. Also, DO saturation within the lagoon was found to be high (mean value ranged between 90.7% and 107.4%) indicating a well oxygenated environment.

The mean suspended solids (as total) concentrations reported between October and November 2017 classified the lagoon as 'clear water' under WFD criteria. However, data collected between January 2016 and April 2016 classified the lagoon as 'turbid' in January 2016 and 'intermediate turbid' in February and April 2016. Total suspended solids concentrations reported to date show considerable variation indicating a very dynamic environment. Suspended solids concentrations in a dynamic environment like Cemlyn lagoon greatly depend on weather conditions. The main two effects observed are, the increased input of freshwater from Cemlyn stream during and after a heavy rain period and the resuspension of sediment during stormy weather generating the wide range of concentrations observed to date.

Cations, anions and metals concentrations reported are considered normal for a transitional environment like Cemlyn lagoon where saline water and freshwater mix to create a brackish environment. Cations and anions concentrations correlate greatly with the salinity observed, with lower concentrations reported in areas of low salinity and vice versa.

Many nutrient concentrations were found below the laboratory's minimum reportable value (MRV) or marginally above this value. All concentrations reported above the MRV were found in line with concentrations observed during the baseline period. This suggests no apparent imbalance or eutrophication of the lagoon.

All other results reported by the laboratory (metals and organic pollutants) were compared with environmental quality standards (EQS) where applicable. No exceedance from annual averages or maximum allowable concentrations values were reported for any of the determinands analysed. Moreover, all concentrations reported by the laboratory are in line with 'Good' chemical status defined by the WFD and consistent with other coastal water with absence of pollution substances.

7. Water Quality in coastal areas around the Wylfa Newydd Development Area

7.1 Introduction

During the construction and pre-construction phase of the Wylfa Newydd Generating Station and Associated Development, it is anticipated that several discharges (e.g. dewatering and sewage) along the coastline around the development area will take place. The potential discharge areas identified (see Figure 7.1) are located in Porth-y-pistyll, Porth Wylfa and Cemaes.

In order to understand and assess the current water quality and physico-chemical conditions in the areas aforementioned, seven sites (see Figure 7.1 and Table 7.1) were monitored monthly from May 2017 onwards, with the exception of September 2017 when no survey work was carried out. Although at present there is an ongoing monitoring programme in place, laboratory results were only available until November 2017 at the time this report was finalised.

The reader must note that although Cemlyn was originally identified as a potential discharge point, it is no longer considered viable due to logistics, cost implications and the potential impact.

Table 7.1 : Coastal water quality sampling locations and area associated.

Site	Target Location	Area associated
CWQ1	53.407557, -4.508179	Cemlyn stream
CWQ2	53.412369, -4.512467	Cemlyn Bay
CWQ3	53.410225, -4.509592	Cemlyn Bay
CWQ4	53.413125, -4.493235	Porth-y-pistyll
CWQ5	53.414071, -4.489482	Porth-y-pistyll
CWQ6	53.415496, -4.467186	Porth Wylfa
CWQ7	53.414484, -4.450246	Cemaes

7.2 Method

Water samples were collected at each site using a sampling bucket. At each location, a subsurface sample was obtained from the coast where the water depth was approximately 0.9 m. The main physico-chemical parameters (temperature, salinity, conductivity, dissolved oxygen and pH) were measured *in situ* using a handheld YSI® or In-Situ® multimeter.

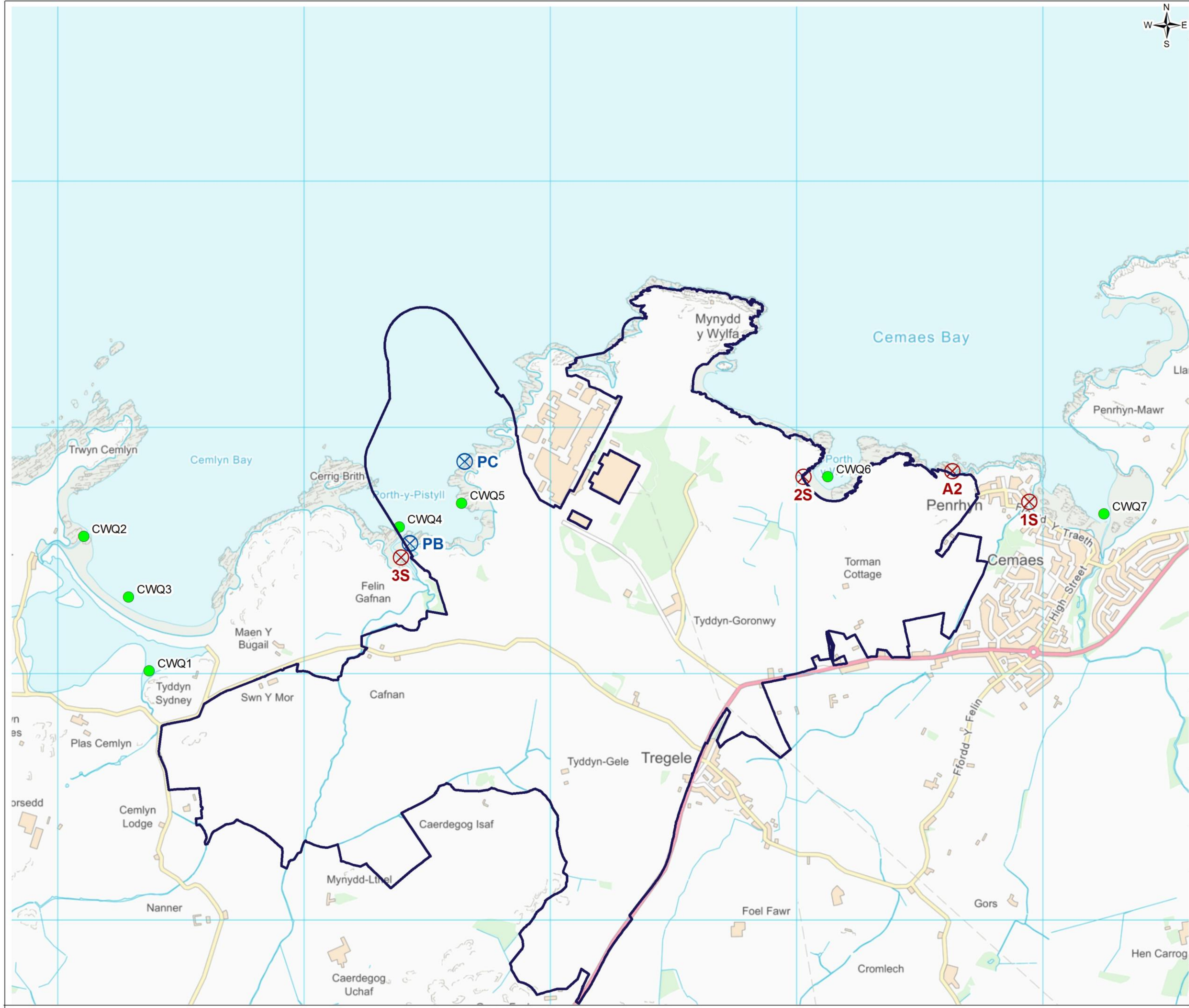
The instrument used to measure all physico-chemical parameters was calibrated and checked following a similar protocol to that described in Section 3.2.3.

The chemical and biochemical determinands monitored were the same as those monitored during the 2014 programme (February 2014 onwards). The reader should refer to Sections 3.2.1, 3.2.1.2 and 3.2.2 for the full list of parameters monitored.

7.2.1 Legislative Standards

The reader should refer to Section 3.2.4.2 for a full list of the legislation and standards that apply. The current EQSs applied to surfaces waters in Wales are summarised by '*The Water Environment (Water Framework Directive) (England and Wales) (Amendment) Regulation 2015 (S.I. 2015 No. 1623)*' and '*The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015*'.

FIGURE 7-1



Contains public sector information licensed under the Open Government Licence v3.0

Legend

- Wylfa Newydd Development
- Marine outfall point
- Marine discharge point
- Coastal water quality sampling sites

Rev.	Date	Purpose of revision	Drawn	Check'd	Rev'd	Appr'd
0	DEC 17	Initial Issue	VG	HY	RW	RB

JACOBS
Kenneth Dibben House, Enterprise Road, Southampton, SO16 7NS
Tel: +44(0)2380111250 Fax: +44(0)2380111251

Client
HORIZON NUCLEAR POWER

Project
WYLFA NEWYDD PROJECT
WATER QUALITY AND PLANKTON REPORT

Drawing Title
COASTAL WATER QUALITY SAMPLING SITES
AROUNDT WYLFA NEWYDD DEVELOPMENT AREA

Drawing Status

Scale @ A3	1:15,000	DO NOT SCALE
Jacobs No.	60PO8099	
Client No.		

Drawing No.
60PO8007_AQE_REP_004_07_01

This drawing is not to be used in whole in or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

7.3 Results

All results are presented by area as identified in Table 7.1. When an area contained two sampling points the mean value was used for that particular area (e.g. Cemlyn Bay and Porth-y-pistyll).

7.3.1 Physico-Chemical parameters

A summary of the physico-chemical properties recorded *in situ* at each area is presented in Table 7.2 below. The reader should note that dissolved oxygen concentrations were not available in July and August 2017 as the instrument used during the survey failed to record these data. Also, the percentage of dissolved oxygen saturation was not available in July 2017 due to interferences with the sensor used.

Table 7.2 : Physico-chemical properties recorded between May 2017 and December 2017 along the north Anglesey coast.

Temperature (°C)	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17
Cemlyn stream	17.90	14.35	21.59	22.36	-	11.39	11.70	3.90
Cemlyn Bay	14.45	13.68	20.73	18.75	-	13.69	11.90	7.75
Porth-y-pistyll	13.65	15.16	19.46	16.94	-	13.83	11.95	8.30
Porth Wylfa	14.60	14.31	19.55	19.17	-	14.16	11.90	8.50
Cemaes	13.70	14.17	19.70	17.85	-	14.11	12.00	8.40
Conductivity (mS cm^{-1})	**May-17**	**Jun-17**	**Jul-17**	**Aug-17**	**Sep-17**	**Oct-17**	**Nov-17**	**Dec-17**
Cemlyn stream	37.321	10.581	11.418	30.949	-	20.350	12.132	15.262
Cemlyn Bay	40.949	42.842	44.489	41.933	-	40.331	38.445	31.058
Porth-y-pistyll	40.004	26.423	39.027	36.116	-	39.893	37.091	33.550
Porth Wylfa	41.049	33.436	45.593	39.143	-	40.619	37.758	34.514
Cemaes	40.331	41.755	32.091	41.125	-	40.120	37.682	32.144
Salinity	**May-17**	**Jun-17**	**Jul-17**	**Aug-17**	**Sep-17**	**Oct-17**	**Nov-17**	**Dec-17**
Cemlyn stream	27.87	7.69	7.00	20.63	-	16.89	9.55	15.32
Cemlyn Bay	33.69	36.15	32.04	32.63	-	33.78	33.54	29.73
Porth-y-pistyll	33.52	20.74	28.52	27.75	-	33.26	32.20	31.85
Porth Wylfa	33.65	26.99	33.46	28.73	-	33.64	32.87	32.67
Cemaes	33.78	34.68	24.02	31.19	-	33.22	32.78	30.28
pH	**May-17**	**Jun-17**	**Jul-17**	**Aug-17**	**Sep-17**	**Oct-17**	**Nov-17**	**Dec-17**
Cemlyn stream	7.85	7.44	7.66	8.59	-	7.92	8.22	8.17
Cemlyn Bay	8.20	7.97	8.20	7.81	-	8.01	8.09	8.11
Porth-y-pistyll	8.32	8.14	8.38	8.13	-	8.12	8.07	8.13
Porth Wylfa	8.35	7.95	7.80	8.16	-	8.07	8.12	8.16
Cemaes	8.22	8.04	8.22	8.17	-	8.09	8.14	8.16
DO (mg L^{-1})	**May-17**	**Jun-17**	**Jul-17**	**Aug-17**	**Sep-17**	**Oct-17**	**Nov-17**	**Dec-17**
Cemlyn stream	5.93	8.26	n/a	n/a	-	8.31	10.32	13.32
Cemlyn Bay	8.45	8.08	n/a	n/a	-	7.14	8.43	10.29
Porth-y-pistyll	8.87	10.33	n/a	n/a	-	8.43	8.54	10.08
Porth Wylfa	9.07	8.34	n/a	n/a	-	7.63	8.39	9.75
Cemaes	8.46	8.31	n/a	n/a	-	7.61	8.69	9.87

DO (% Saturation)	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17
Cemlyn stream	73.9	86.0	n/a	138.5	-	84.6	101.0	112.4
Cemlyn Bay	101.9	98.9	119.8	114.9	-	84.8	96.5	104.9
Porth-y-pistyll	105.1	118.9	145.2	113.0	-	100.0	97.0	105.5
Porth Wylfa	109.7	97.7	102.8	110.6	-	91.4	95.6	103.1
Cemaes	100.5	101.2	123.3	106.9	-	90.9	99.0	102.5

7.3.2 Laboratory Analysis Results

The mean values reported for the whole survey area (all samples collected) can be found in Appendix J.

7.3.2.1 Physico-Chemical Determinands

7.3.2.1.1 Organic Carbon, Total and Dissolved (TOC and DOC)

A summary of the organic carbon concentrations reported for each area can be found in Table 7.3. When all coastal areas monitored (excluding Cemlyn stream) are considered as a whole, the mean TOC reported between May and November 2017 was 1.3 mg L^{-1} while the mean DOC was 1.11 mg L^{-1}.

Table 7.3 : Minimum, maximum and mean TOC and DOC reported between May and November 2017.

Area monitored	Total Organic Carbon (TOC) – mg L^{-1}			Dissolved Organic Carbon (DOC) – mg L^{-1}		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Cemlyn stream	4.0	9.1	5.8	3.06	8.11	5.39
Cemlyn Bay	0.8	3.3	1.2	0.73	2.56	1.00
Porth-y-pistyll	0.8	1.7	1.2	0.94	1.30	1.07
Porth Wylfa	0.8	2.9	1.3	0.87	2.35	1.45
Cemaes	0.9	1.9	1.4	0.89	1.43	1.05

7.3.2.1.2 Biological Oxygen Demand (BOD)

A summary of the BOD concentration reported for each area can be found in Table 7.4. Almost half of the samples analysed (20 out of 41) were reported as below MRV. The mean value reported for all coastal areas, with the exception of Cemlyn stream, was also reported as below MRV (1.00 mg L^{-1}).

Table 7.4 : Minimum, maximum and mean BOD reported between May and November 2017.

Area monitored	BOD (mg L^{-1})		
	Minimum	Maximum	Mean
Cemlyn stream	1.12	2.69	1.66
Cemlyn Bay	<1.00	1.59	<1.00
Porth-y-pistyll	<1.00	2.19	<1.00
Porth Wylfa	<1.00	1.37	<1.00
Cemaes	<1.00	1.59	<1.00

7.3.2.1.3 Total Suspended Solids (TSS)

A summary of the TSS concentration reported for each area can be found in Table 7.4.

Table 7.5 : Minimum, maximum and mean TSS reported between May and November 2017.

Area monitored	TSS (mg L^{-1})		
	Minimum	Maximum	Mean
Cemlyn stream	8.2	82.3	29.4
Cemlyn Bay	4.0	19.8	9.7
Porth-y-pistyll	<3.0	10.5	6.1
Porth Wylfa	<3.0	10.4	6.5
Cemaes	<3.0	21.9	10.8

7.3.2.2 Cations and Anions

The mean value reported for each survey area as well as the range of values reported between May and November 2017 can be found in Table 7.6. Bromate concentrations were reported as below MRV (0.1 mg L^{-1}) in all samples.

Table 7.6 : Mean cations and anions concentrations reported for each area monitored between May and November 2017. The range of the concentrations reported is given in brackets.

Area monitored	Bromide	Calcium	Potassium	Sodium	Sulphate
	Units: mg L^{-1}				
Cemlyn stream	32.1 (18.5 - 52.9)	236 (13.9 - 355)	242 (11 - 347)	5877 (305 - 9000)	1531 (75.8 - 2330)
Cemlyn Bay	63.5 (56.1 - 68.3)	389 (351 - 419)	412 (347 - 497)	9990 (9010 - 10900)	2639 (2370 - 2770)
Porth-y-pistyll	62.4 (56 - 66)	384 (356 - 419)	402 (353 - 477)	9904 (9180 - 10600)	2598 (2320 - 2820)
Porth Wylfa	62.2 (55.7 - 67)	384 (368 - 399)	393 (351 - 440)	9968 (9170 - 10600)	2600 (2400 - 2790)
Cemaes	62.1 (56.3 - 66.7)	380 (361 - 400)	395 (339 - 449)	9825 (8820 - 10700)	2593 (2370 - 2780)

7.3.2.3 Nutrients

Nutrients concentrations reported at each survey area were found to be relatively low and comparable to those concentrations reported during the baseline monitoring programme (see Section 3.3.2.3). The majority of the nitrogen concentrations (Table 7.7) were reported as below MRV with the exception of most samples collected at Cemlyn stream.

Un-ionised ammonia concentrations (Table 7.8) were reported as below the relevant EQS in all samples. The highest concentration reported between May and October 2017 was 5.02 µg L^{-1} at Cemlyn stream. If only coastal areas are considered the highest concentration reported would have been 1.88 µg L^{-1}.

Similarly, orthophosphate and silicate (Table 7.9) concentrations reported between May and November 2017 were found to be relatively low and comparable to those concentrations reported for the area during the baseline monitoring programme.

Table 7.7 : Mean nitrogen concentrations reported in its different forms at each monitored area between May and November 2017.

Area monitored	Nitrogen (as N)	Total organic Nitrogen (as N)	Ammoniacal nitrogen (as N)	Dissolved inorganic nitrogen (as N)	Total oxidised nitrogen (as N)	Nitrite (as N)
	Units: mg L^{-1}					
Cemlyn stream	1.63	<0.933	0.10	0.909	0.83	0.0174
Cemlyn Bay	0.17	<0.980	<0.02	<0.120	<0.10	<0.0040

Area monitored	Nitrogen (as N)	Total organic Nitrogen (as N)	Ammoniacal nitrogen (as N)	Dissolved inorganic nitrogen (as N)	Total oxidised nitrogen (as N)	Nitrite (as N)
	Units: mg L^{-1}					
Porth-y-pistyll	0.19	<0.980	<0.02	<0.120	<0.10	<0.0040
Porth Wylfa	0.24	<0.980	<0.02	<0.120	<0.10	<0.0040
Cemaes	0.25	<0.980	<0.02	<0.120	<0.10	<0.0040

Table 7.8 : Mean un-ionised ammonia concentrations reported at each area between May and November 2017. The range of the concentrations reported is given in brackets.

Area monitored	Un-ionised ammonia (as N) in µg L^{-1} (EQS = 21 µg L^{-1})
Cemlyn stream	2.428 (0.729 - 5.020)
Cemlyn Bay	<0.680 (<0.237 - <1.700)
Porth-y-pistyll	<0.869 (<0.451 - <1.880)
Porth Wylfa	<0.836 (<0.474 - <1.220)
Cemaes	<0.785 (<0.548 - <1.210)

Table 7.9 : Mean orthophosphate and silicate concentrations reported at each survey area between May and November 2017.

Area monitored	Orthophosphate	Silicate (as SiO_2)
	Units: mg L^{-1}	
Cemlyn stream	0.017	3.22
Cemlyn Bay	0.012	0.20
Porth-y-pistyll	0.012	0.39
Porth Wylfa	0.015	0.42
Cemaes	0.014	0.46

7.3.2.4 Metals

All metals concentrations reported between May and November 2017 at each survey area were found below the relevant EQSs. Moreover, a number of metals (selenium, cobalt, tin, iron, vanadium and the dissolved fraction of mercury) were reported below the laboratory MRV in all samples. Cadmium, chromium and the total fraction of mercury were also reported as below MRV in most samples, with very few exceptions. Cadmium was reported marginally above MRV in one sample collected in Cemlyn stream in May 2017, chromium was reported marginally above MRV in three samples (highest concentration reported above the MRV was 0.914 µg L^{-1} in a sample collected in June 2017 in Cemlyn Bay) while the total fraction of mercury was reported marginally above MRV in one sample collected in Porth-y-pistyll in November 2017.

Similarly, manganese was reported below the MRV in most samples collected, however most of the samples collected at Cemlyn stream were reported above this value, with concentrations reported between <20 µg L^{-1} and 87.7 µg L^{-1}. The mean value observed in Cemlyn stream was 49.6 µg L^{-1}. Manganese concentrations reported in all others samples were found below MRV with the exception of two samples reported marginally above this value (one in Cemlyn Bay and one in Porth-y-pistyll).

A summary of all other metals concentrations reported between May and October 2017 can be found in Table 7.10.

Table 7.10 : Mean metals concentrations reported above MRV at each site. The range of concentrations reported between May and November 2017 are presented in brackets.

Area monitored	Arsenic	Copper	Lead	Nickel	Zinc	Boron
	Units: µg L^{-1}					
Cemlyn stream	0.65 (<1.00 - 1.27)	1.407 (0.816 - 2.42)	0.065 (<0.040 - 0.124)	0.950 (0.826 - 1.12)	3.072 (0.519 - 5.870)	2494 (<700 - 3790)
Cemlyn Bay	1.40 (1.24 - 1.58)	0.669 (0.477 - 1.24)	0.041 (<0.040 - 0.09)	0.471 (0.323 - 1.2)	2.143 (0.779 - 4.640)	3575 (<700 - 4530)
Porth-y-pistyll	1.27 (<1.00 - 1.47)	0.624 (0.486 - 0.809)	0.038 (<0.040 - 0.158)	0.381 (<0.300 - 0.843)	1.963 (0.734 - 3.470)	3839 (<700 - 4540)
Porth Wylfa	1.25 (<1.00 - 1.53)	0.668 (0.466 - 1.18)	0.031 (<0.040 - 0.063)	0.377 (<0.300 - 0.653)	2.398 (1.070 - 4.960)	4192 (3950 - 4350)
Cemaes	1.33 (1.22 - 1.4)	0.795 (0.653 - 1.02)	0.031 (<0.040 - 0.0601)	0.408 (0.340 - 0.597)	2.18 (1.690 - 3.290)	4142 (3900 - 4380)

7.3.2.5 Organic Compounds

The majority of organic compounds monitored between May and November 2017 (TPHs, PAHs, PCBs, VOCs and Phenols) were reported as below the MRV in all samples collected. However, several exceptions were reported. Compounds reported above the MRV (fluorene, naphthalene, phenanthrene, phenols dimethylphenols, methylphenols, benzene, 1,2-dimethylbenzene, 1,2,4-trimethylbenzene, bromodichloromethane, tribromomethane, chlorodibromomethane, trichloromethane, dimethylbenzene, ethylbenzene, toluene and di-2-ethylhexyl phthalate) were found at concentrations marginally above the MRV, in all cases well below their relevant EQS.

Generally, detection of most compounds aforementioned was limited to very few samples. The exceptions were phenol and tribromomethane, detected more regularly between May and November 2017. The maximum phenol concentration reported was 0.243 µg L^{-1}, while the maximum concentration reported for tribromomethane was 0.75 µg L^{-1}. It must be noted that phenol is expected to be widely detected as this compound is widely used industrially and widely available. In the case of tribromomethane, this particular compound was detected in the majority of samples collected in Porth-y-pistyll and occasionally elsewhere.

7.3.2.6 Cyanide

All results were reported below their MRV (0.5 mg L^{-1} for total cyanide as CN and 0.005 mg L^{-1} for free cyanide as CN).

7.4 Discussion

Temperature values recorded within Cemlyn Bay, Porth-y-pistyll, Porth Wylfa and Cemaes between May and December 2017 were found within the expected values when compared with previous data collected during baseline surveys. Similarly, salinity values recorded between May and December 2017 also are comparable to those recorded during the baseline period. Physico-chemical properties recorded in Cemlyn stream, particularly, temperature, conductivity and salinity corresponded to a greater freshwater input.

DO values recorded in all areas are 'High' according with current WFD classification. The minimum DO concentration recorded was 5.93 mg L^{-1} in Cemlyn stream in May 2017. If only coastal areas are considered, the minimum concentration would be 7.14 mg L^{-1} in Cemlyn Bay in October 2017.

The mean suspended solids (as total) concentrations reported between May and November 2017 classified the coastal area as 'clear' or 'intermediate turbid' water under WFD criteria.

Cations, anions and metals concentrations reported in all coastal areas, are considered normal and in line with the data gathered during the baseline period.

Most nutrient concentrations were found below the laboratory’s minimum reportable value (MRV) or marginally above this value.

The vast majority of organic compounds were reported to be below the MRV, however several compounds were occasionally reported above. In particular, tribromomethane was detected more regularly between May and November 2017. This compound was detected in the majority of samples collected in Porth-y-pistyll and occasionally elsewhere with a maximum concentration reported of 0.75 $\mu g\ L^{-1}$.

All results reported by the laboratory were compared with environmental quality standards (EQS) where applicable. No exceedance from annual averages or maximum allowable concentration values were reported for any of the determinands analysed. Moreover, all concentrations reported by the laboratory are in line with ‘Good’ chemical status defined by the WFD and consistent with other coastal water with absence of pollution substances.

8. Phytoplankton

8.1 Introduction

This section presents the results of the phytoplankton surveys undertaken between May 2010 and September 2014, encompassing:

- two full years of the monitoring programme (May 2010 – April 2012) for the original five sampling sites (Sites 1 to 5[10]);
- an additional 14 months of data (August 2011 – October 2012) for Site 6 only, which was located within 500 m of the CW intake proposed location at Porth-y-pistyll and
- seven months of data (March – September 2014) for the revised sampling sites (Sites 2, 4, 6 and 7); Site 7 was located in Cemlyn Bay, just west of Porth-y-pistyll.

Sampling sites were selected to fall within either near-, mid- or far-field zones in relation to the Wylfa Newydd Generating Station. These zones are defined by the dominant physical mixing processes of the CWS discharge with the ambient waters and are defined by EA (2010). The near-field is determined by the initial momentum and buoyancy of the CWS discharge; the mid-field by dilution and turbulent mixing by tides and winds; and the far-field only by residual currents and weather conditions as buoyancy and temperature differences from ambient are negligible (EA, 2010). In reality these zones are in a constant state of flux caused by prevailing tidal and weather conditions. The sampling sites reported here were selected based on early Delft3D modelling of the predicted CWS discharge and its consequential plume dispersion. Revised Delft3D thermal and hydrodynamic modelling being undertaken for the latest design of the Wylfa Newydd Generating Station is expected to demonstrate the continued validity of the selected sites.

Sampling was carried out on a monthly basis until October 2012, encompassing full seasonal variations of phytoplankton communities and pigments around the north Anglesey coast. In 2014 samples were collected monthly during the phytoplankton growing period (March – September). Due to the large tidal excursion, samples were collected at sites during neap and spring tidal cycles, and over flood, ebb and slack tides.

8.2 Methods

8.2.1 Survey Methodology

All surveys followed methods agreed with relevant stakeholders and statutory regulators prior to surveying.

Phytoplankton samples were initially collected each month (except December 2011, due to adverse weather conditions), with an interval of at least ten days between sampling collections. All sites were sampled on both flood and ebb tides between May 2010 and October 2012, with the exception of November 2011 and January 2012 when it was considered that one sample per site at either ebb or flood would be sufficient due to the very low plankton activity observed during these months. Sampling continued for two full years at the original five sites until April 2012 inclusive. Site 6 was introduced in August 2011 to monitor the area in the proximity of the CW intake proposed location. Sampling at Site 6 continued until October 2012 in order to acquire at least 12 months' data for this site. Phytoplankton sampling resumed from March 2014 until September 2014 at Sites 2, 4, 6 and the newly introduced Site 7, at one random tidal state. The survey dates are detailed in Table 2.1.

As with the water quality sampling, surveys took place on board the vessel 'SeeKat C'. The locations of the sample sites were identical to the water quality sites listed in Table 2.2 and shown in Figure 2.1.

8.2.2 Sampling Methodology

Water samples were analysed for chemical and biological parameters as described in Section 3. Samples for biological parameters were collected using an integrated water sampling technique (Lund tube), which allows collection of water samples from across a depth range (surface to 10 m depth).

[10] All sampling sites are coincident with those of the WQ surveys and are numbered the same. However, the prefix WQ has been removed.

Each water sample was homogenised and split into two sub-samples to allow for phytoplankton species identification and pigment analyses. The pigment sub-samples were analysed for a full pigments suite using High Performance Liquid Chromatography (HPLC); in 2014 these samples were analysed for chl-a only.

Phytoplankton samples for species identification were stored in 250 mL PET bottles, labelled with Site, Tide, Date and Time and preserved with concentrated Lugol's Iodine solution (approximately 1 mL) to give a light orange colour. The samples were then wrapped in tin foil and stored in a cool, dark place to prevent degradation prior to analysis.

Between May 2010 and October 2012, water was collected in three 1 L PET bottles at each site and tidal state for HPLC analysis. Water samples were then refrigerated and transported back to the Jacobs Southampton Laboratory for filtration. The samples were homogenised and filtered through a 47 mm GFC filter using an electric vacuum pump; a minimum of 2 L was passed through each filter paper; representing one sample. The filter paper was then folded in half (sample sides together) before being wrapped in tin foil and frozen. Each sample was clearly labelled with the amount of water filtered so that accurate calculations of pigment concentrations could be made. The filter samples were then transported to the National Oceanography Centre (NOC), University of Southampton for analysis. In 2014, at each site water was collected in a 1 L green PET bottle and transported to an accredited laboratory within 24 hrs for chl-a analysis.

Alongside phytoplankton sampling, physico-chemical parameters were collected using the methods described in Section 3.2.3.

8.2.3 Sample Analysis

8.2.3.1 Species Identification Method

Phytoplankton taxonomic analysis to species level (or as high taxonomic resolution as practically possible) was undertaken following the Utermöhl or Inverted Microscope method (Lund *et al*., 1958).

A 25 mL sedimentation chamber consisting of a clear plastic cylinder, a metal plate, a glass disposable coverslip base plate and glass cover plate was used (see Figure 8.1). The chamber was prepared by placing a coverslip base plate at the bottom of the metal plate and screwing the plastic cylinder into the ring.

The sample for analysis was mixed by slowly inverting the bottle up and down about 100 times and not by shaking the bottle, so as to avoid the formation of air bubbles.

The chamber was then placed on a level surface and filled with the mixed sample until it started to overflow. A cover slip was placed over the chamber by sliding it from the side, so that the excess volume of water was discarded. The chamber was then allowed to settle for at least 10 hrs or overnight, without being disturbed.

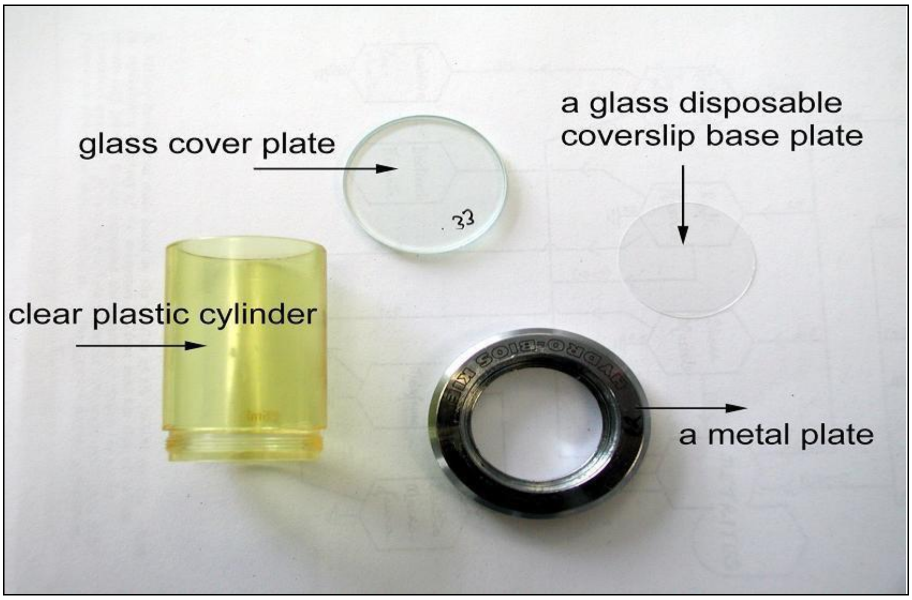


Figure 8.1 : Sedimentation counting chamber.

All analysis was completed using an inverted microscope. Initially a check was made at x100 magnification (x10 objective) to ensure distribution of organisms was even throughout the chamber.

Most identification was carried out at x200 magnification by scanning the whole chamber in a left to right motion. In the case of very abundant organisms only half of the chamber was counted, whereas smaller organisms were identified at x400 magnification. The number of cells counted was scaled up and presented as cells L^{-1}.

Phytoplankton was identified to the highest possible level according to contemporary standard taxonomic lists; in most cases identification was at genus or species level. Ciliates and tintinnids were also counted, even though these are microzooplankton, as they form an important link between phytoplankton and macrozooplankton and are too small to enumerate using macrozooplankton methods.

The accuracy of the counts was ±20% if 100 individuals were counted and less than ±10% if 400 or more individuals were counted (Lund *et al*., 1958).

8.2.3.2 High Performance Liquid Chromatography (HPLC) Method

HPLC analysis was undertaken at NOC, University of Southampton. Each filter paper was treated with 90% acetone and individually subjected to sonication (application of sound energy to break up phytoplankton cells). The sample was then filtered through 0.2 µm filter paper into prepared sample vials and loaded immediately into an autosampler. The HPLC analytical system was set up for the Gibbs method and analysed using ChromQuest software for chromatographic traces.

8.2.3.3 Chl-a Analysis

In 2014, chl-a analysis was undertaken at National Laboratory Services, Starcross. The water sample was filtered through a GFF (Glass Fibre Filters) filter paper and chl-a extracted in acetone overnight. Chl-a was measured in the acetone using a fluorometer.

8.2.4 Data Analysis

As part of the analysis of results, multivariate statistical tests were performed using PRIMER 6TM (Clarke and Gorley, 2006).

8.2.4.1 Community Analysis

The community analysis used a multivariate approach, where each taxonomic level (species, genus) or phytoplankton group (see Appendix K, Table K.1 for a taxonomic list) was treated as a separate variable, enabling an assessment of complex patterns within large datasets. The multivariate analysis compared differences between all species (or each of the other taxonomic levels or phytoplankton groups) and their relative abundances between samples and sites. The analysis allowed identification of samples with similar communities.

All data were square root transformed to remove skew and down-weight the influence of numerically dominant taxa. Similarity matrices were created based on Bray-Curtis similarity which is suitable for biotic data (Clarke and Gorley, 2006).

A two-way crossed ANOSIM (analysis of similarity) for no replicates was used to test for differences between samples taken on the same survey, whereas a two-way crossed ANOSIM was used to compare seasons and monitoring years. The two-way crossed ANOSIM only compares similarities between samples within the same level of the second factor, therefore it is appropriate to use when there is need to separate seasonal from spatial variation or seasonal from year-on-year variation (i.e. difference in the same season from year to year and differences between seasons of the same year). This approach can be viewed as a non-parametric version of a multivariate ANOVA (MANOVA) (Clarke and Gorley, 2006). The ANOSIM was carried out on Bray-Curtis matrices of the different taxonomic levels, with 999 permutations, using season (spring, summer, autumn, winter), monitoring years (1 to 5), sites and tide as factors.

To further investigate and visualise differences in communities across factors (months, seasons, monitoring years), non-metric Multidimensional Scaling (MDS) (25 restarts, Kruskal fit) was carried out on the Bray-Curtis similarity matrix. MDS constructs a sample 'map' whose distances reflect statistically tested 'true' differences between the sites. Put simply, the closer a sample is to another sample on the ordination plot the more similar the samples are to each other.

Where ANOSIM found significant differences, a SIMPER test was used to investigate which individual taxa were driving the Bray-Curtis similarity within groups and dissimilarity between these groups. The test ranks, in order of importance, each taxon by calculating their overall percentage contribution to the average dissimilarity between each group. The Bray-Curtis similarity (or dissimilarity) coefficient takes values between 0 (total dissimilarity) and 100% (total similarity).

In addition to the multivariate analysis, univariate data analysis which concentrated complex ecological data into a single metric, such as Shannon-Wiener diversity, was also performed.

The average species (or taxa) richness (S) and Shannon-Wiener diversity index (H') were calculated for each survey month. Species or taxa richness is simply the total number of species (or taxa) whereas Shannon-Wiener diversity provides a measure of species/taxa diversity by incorporating both species richness and equitability components, i.e. how evenly the individuals are distributed among the different species/taxa. The value of Shannon-Wiener diversity is increased either by the addition of more species or by having a greater species evenness.

8.2.4.2 Pigment Analysis

Pigment analysis only included 2010 – 2012 HPLC data as in 2014 samples were analysed for chl-a only. Prior to statistical analysis, all pigment data were $\log_{(x+1)}$ transformed to remove skew and down-weight the influence of numerically dominant variables. Similarity matrices were created based on Euclidean distance which is appropriate for abiotic data (Clarke and Gorley, 2006).

ANOSIM testing was used to detect differences between sites, tidal states, months, seasons and monitoring years.

A correlation-based Principal Components Analysis (PCA) was used to assess the pigment data and their distribution between sites, tides, seasons and months. PCA is an appropriate multivariate statistical approach to assessing environmental variables, where zero values do not need to be treated in a special way and ‘joint absences’ should not be ignored (Clarke and Warwick 2001), as is the case with species abundance data.

The principle of PCA is to create new variables which explain as much of the information in the dataset as possible. These new variables, known as principal components, are linear combinations of the original ones. The first principal component (PC1) is chosen to explain the largest possible amount of the information in the data; the second principal component (PC2) is designed to be as different from the first as possible and explain the second largest amount of information; and so on. The amount of information explained by each principal component is called an eigenvalue, whereas eigenvectors are the linear combinations of the original variables and describe how variables contribute to each principal component. The PCA plots and tables should be read together for best understanding of the analysis output.

8.3 Results

A two-way crossed ANOSIM analysis (no replicates) using site/tide and month/year as factors, indicated that there were no statistically significant differences in phytoplankton community structure between samples taken at different sites and tides in any one survey (Global R = 0.000, $p = 0.485$). Therefore, all samples taken during each monthly survey have been considered as replicates for that specific month for the survey area.

8.3.1 Community Analysis

8.3.1.1 General Observations

A total of eight phyla consisting of 13 classes and 36 orders have been recorded off north Anglesey. In total, 84 species belonging to 53 genera have been identified, with an additional 24 identified to genus level.

A full taxonomic list of phytoplankton off north Anglesey (including ciliates and tintinnids) identified between May 2010 and October 2012 inclusive is given in Appendix K0 (Table K.1). It should be noted that a number of phytoplankton species as well as families, classes and phyla have recently changed names and therefore the most up to date names, as of November 2014, are listed in this report. The synonymous names are given alongside the latest accepted nomenclature (WoRMS Editorial Board, 2015) (Appendix K(Table K.1)).

A number of cells could not be identified to species/genus level, so these were placed in one of the following groups:

- armoured and naked dinoflagellates;
- centric and pennate diatoms;
- smooth and spiny dinoflagellate cysts;
- ciliates;
- coccolithophorids;
- cryptophytes;
- cyanophytes;
- prasinophytes;
- prymnesiophytes;
- raphidophytes;
- microflagellates; and,
- tintinnids.

These groups were used together with the 84 species and 77 genera in the statistical community analysis.

Diatoms (phylum Ochrophyta) were the most abundant group. Diatom abundance peaked during June in 2010 and 2014, and during May in 2011 and 2012. The highest cell densities were observed in May 2011

(80,092 cells L^{-1}) and were double the densities of May 2012 (39,240 cells L^{-1}), quadruple those of June 2010 (22,284 cells L^{-1}) and 1.5 times those of June 2014 (52,430 cells L^{-1}) (Figure 8.2).

Dinoflagellates (phylum Myzozoa) were the second most abundant group and peaked at the same time as diatoms in 2010 (2,173 cells L^{-1}) and 1-2 months later in 2011, 2012 and 2014; however, their maximum abundance was one to two orders of magnitude lower than that of diatoms.

Other phytoplankton groups appeared at low abundances throughout the monitoring period, with the exception of a peak in prymnesiophyte abundance, dominated by *Phaeocystis globosa*, observed during May 2010 (2,187 cells L^{-1}) (Figure 8.2). The microzooplankton groups of ciliates and tintinnids were also observed at low densities (up to 747 and 380 cells L^{-1}, respectively). Microflagellates were observed only once during the monitoring period, at very high abundances, in April 2012 (280,418 cells L^{-1}) (Figure 8.2).

Figure 8.3 shows the main phytoplankton genera contributing to total phytoplankton abundance (excluding microflagellates); on average, 18 genera cumulatively accounted for 81% of total abundance. *Rhizosolenia* was the dominant genus in June 2010, whereas, *Guinardia* dominated the phytoplankton abundance peaks in spring 2011, 2012 and 2014. The 2012 spring peak was followed by high abundances of *Leptocylindrus* later in the summer. *Paralia* was the most abundant genus during autumn and winter months (although winter months were only sampled in 2011 and 2012).

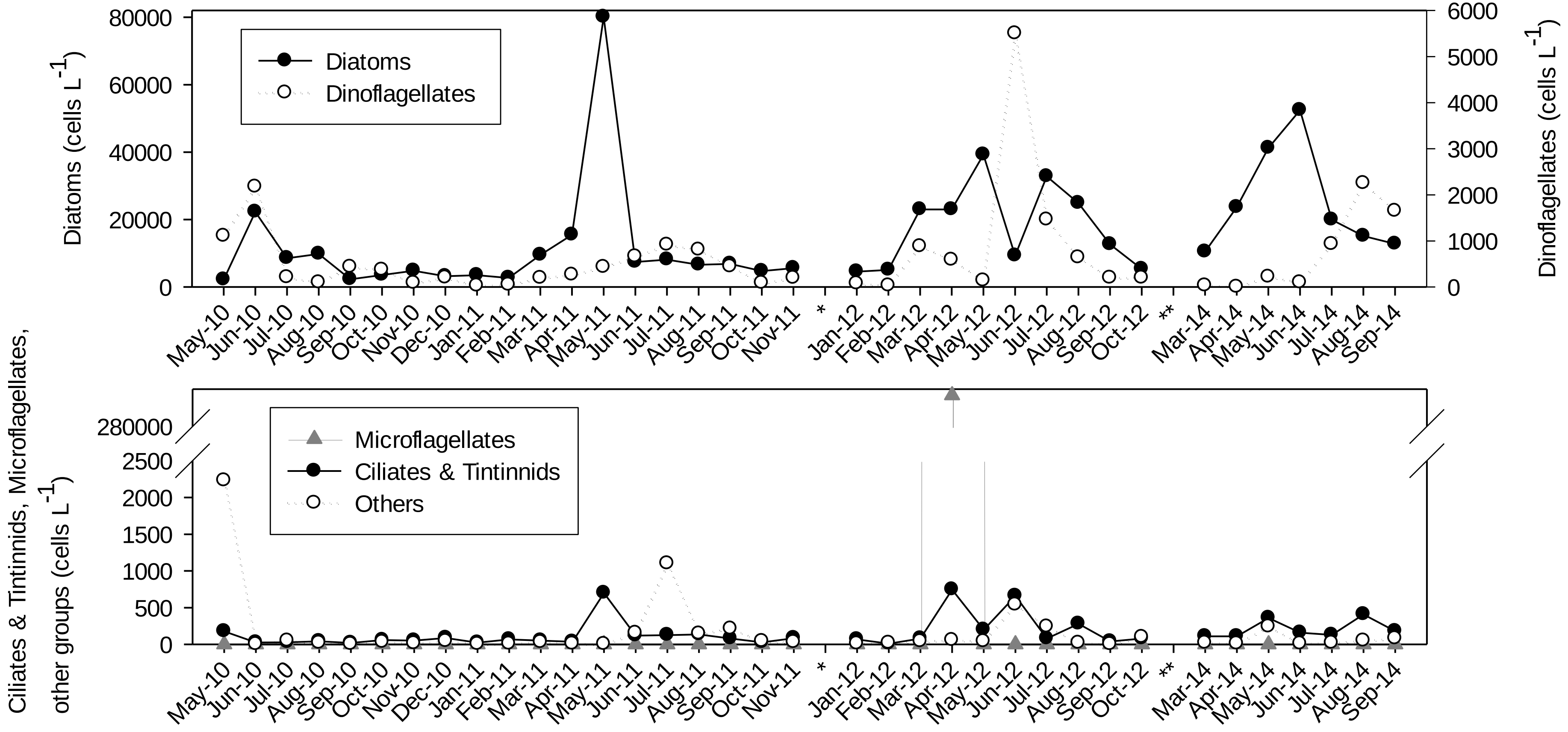


Figure 8.2 : Average monthly abundance of phytoplankton groups. Note the different scales. 'Others' includes prymnesiophytes, cryptophytes, cyanophytes, dictyochophytes, chrysophytes, euglenophytes, chlorophytes, prasinophytes and raphidophytes. Phytoplankton samples were not taken in December 2011 (*) or in 2013 (**).

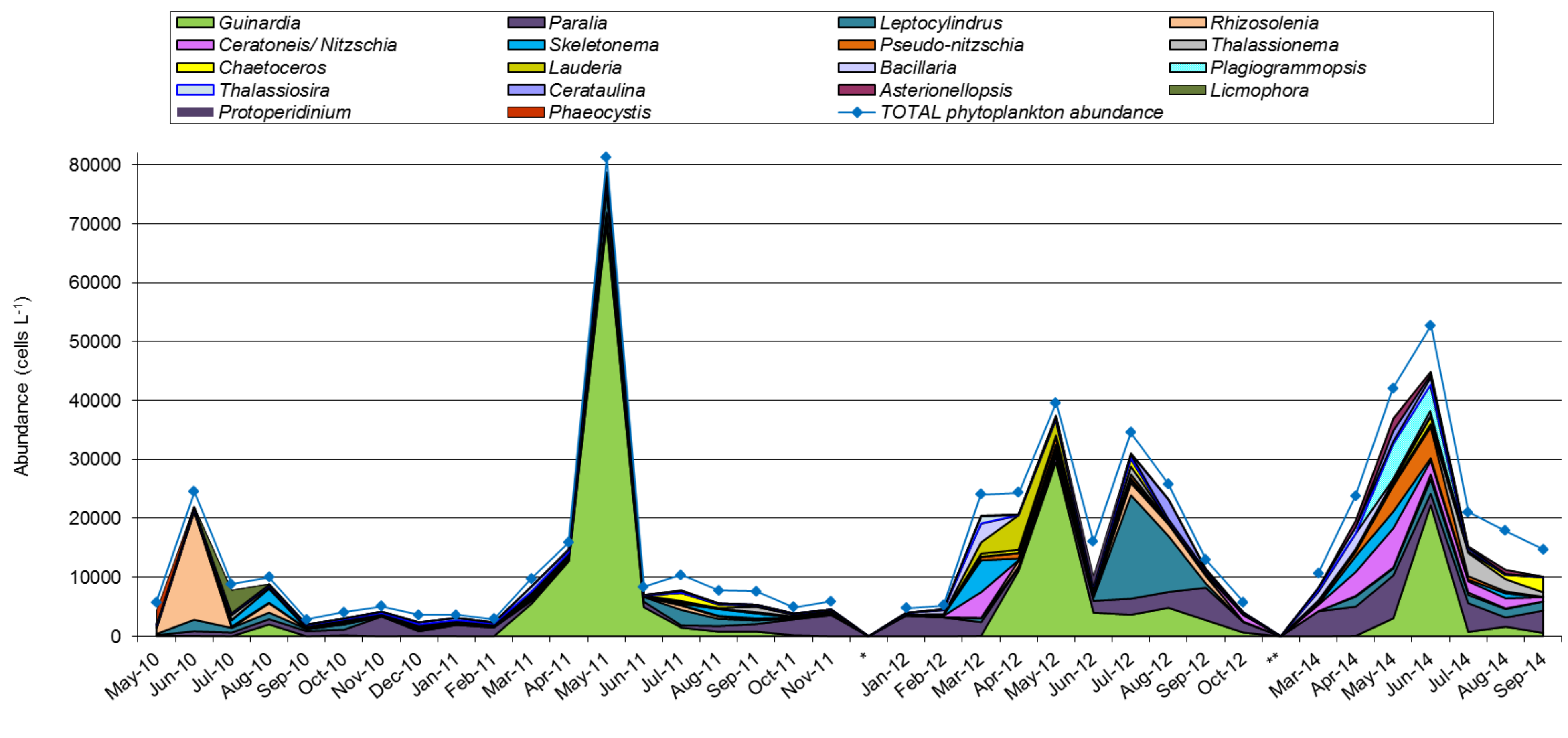


Figure 8.3 : Main phytoplankton genera contributing on average 81% to total phytoplankton abundance (excluding microflagellates). Phytoplankton samples were not taken in December 2011 (*) or in 2013 (**).

Phytoplankton taxa richness (S) and Shannon–Wiener diversity index (H'), were calculated using whole community data. Both of these indices fluctuated during the monitoring period (Figure 8.4), with highest diversity (H') observed during late spring and summer and lowest during winter. Taxa richness was the highest in June 2012 (35.5), when the highest Shannon–Wiener diversity was also observed (2.9). This was based, however, on only two samples from Site 6 located in Porth-y-pistyll. Looking at the months where more than one site was sampled, highest taxa richness and Shannon–Wiener diversity were observed in July and August 2014, (values of 33.5 and 2.8 respectively). As the Shannon–Wiener diversity is an indicator of taxa richness as well as evenness of the abundance between taxa, this means that the summer months following the spring peak in phytoplankton abundance in each year had the highest number of taxa recorded with relatively low dominance by any of these taxa. This is confirmed by the phytoplankton composition shown in Figure 8.3. In contrast, the lowest taxa richness was observed during the winter months (ranging between 9 and 17). In winter 2012, Shannon–Wiener diversity was also especially low (1.0 – 1.3), indicating a small number of taxa largely dominated by one of these taxa. Indeed, the winter months were dominated by the genus *Paralia* (Figure 8.3).

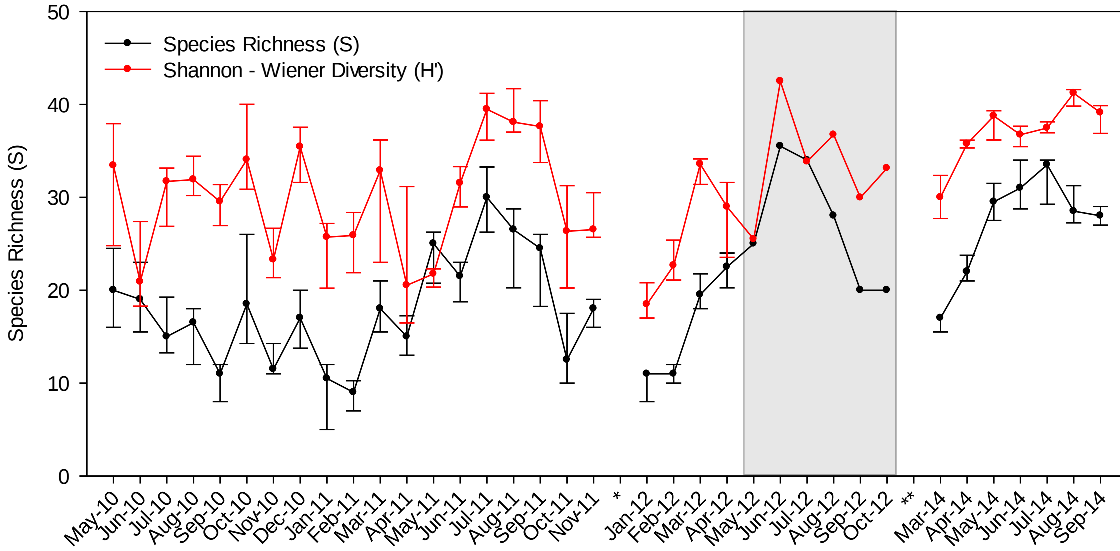


Figure 8.4 : Taxa richness and Shannon-Wiener diversity index for each month of the monitoring programme, displayed as median values, with the 25th and 75th percentiles as error bars. Phytoplankton samples were not taken in December 2011 (*) or in 2013 (**). Error bars not displayed between May 2012 and October 2012 as only Site 6 was sampled (two samples taken).

Multivariate statistical analysis of whole community data between May 2010 and September 2014 also showed some differences between the phytoplankton community of the spring and summer months compared to that of autumn and winter. The 3-D MDS plots (Figure 8.5) show a degree of seasonal separation, with some overlap between consecutive months and seasons. Moreover, there was clustering between the samples that was not associated with seasonal or year-on-year differences, and was due to differing abundance of diatoms in the samples (Figure 8.5; 2-D plot). No differences were evident between the first two monitoring years, although monitoring years three and five seemed to cluster closer together and were associated with high diatom abundances. This was probably due to the absence of winter samples, with predominantly low abundance of diatoms.

A two-way crossed ANOSIM analysis of the phytoplankton communities indicated a degree of seasonal differences (Global R = 0.463, p = 0.001) as well as some differences between the same season of different years (Global R = 0.351, p = 0.001), in agreement with the MDS analysis. Pairwise comparisons suggested greater differences between spring and other seasons and also between summer and winter (Table 8.1), in agreement with the results of MDS analysis. Pairwise comparisons between years suggested greater differences between years 2010 and 2012 and between year 2014 and previous years (Table 8.1).

Table 8.1 : Pairwise comparisons of seasons across monitoring years and monitoring years across seasons (two-way crossed ANOSIM).

ANOSIM pairwise tests					
Groups (seasons)	**R**	***P***	**Groups (monitoring years)**	**R**	***P***
Spring, summer	0.401	0.001	2010, 2011	0.357	0.001
Spring, autumn	0.529	0.001	2010, 2012	0.501	0.001
Spring, winter	0.627	0.001	2010, 2014	0.409	0.001
Summer, autumn	0.360	0.001	2011, 2012	0.304	0.001
Summer, winter	0.646	0.001	2011, 2014	0.483	0.001
Autumn, winter	0.290	0.001	2012, 2014	0.447	0.001

A SIMPER analysis was used to determine which phytoplankton taxa were responsible for the differences observed between different seasons and the same season of different years; the analysis output is detailed in Appendix K Table K.2 and Table K.3.

SIMPER analysis indicated that high densities of the genus *Guinardia* during spring and, to a lesser extent, *Lauderia* were responsible for differences between spring and all other seasons, when the densities of these genera were significantly lower. Differences between summer and other seasons were due to a contribution to dissimilarity of a number of species rather than one or two. During summer, *Leptocylindrus* and *Rhizosolenia* densities were relatively high compared to other seasons, whereas autumn and winter were characterised by high densities of *Paralia*. This is in agreement with the pattern described in Figure 8.3.

Differences between years 2010 and 2012 were mainly due to higher abundances of the genera *Paralia*, *Guinardia, Lauderia* and *Ceratoneis* in 2012 compared to 2010. Differences between year 2014 and previous years were largely due to differing densities of the same abundant species/genera. Abundances of the genera *Paralia* and *Ceratoneis* were generally higher in 2014, whereas species of *Guinardia* were less abundant in 2014 than in 2011 and 2012, but more abundant than in 2010. *Leptocylindrus* densities were also higher in 2014 than in previous years.

Phytoplankton – whole community

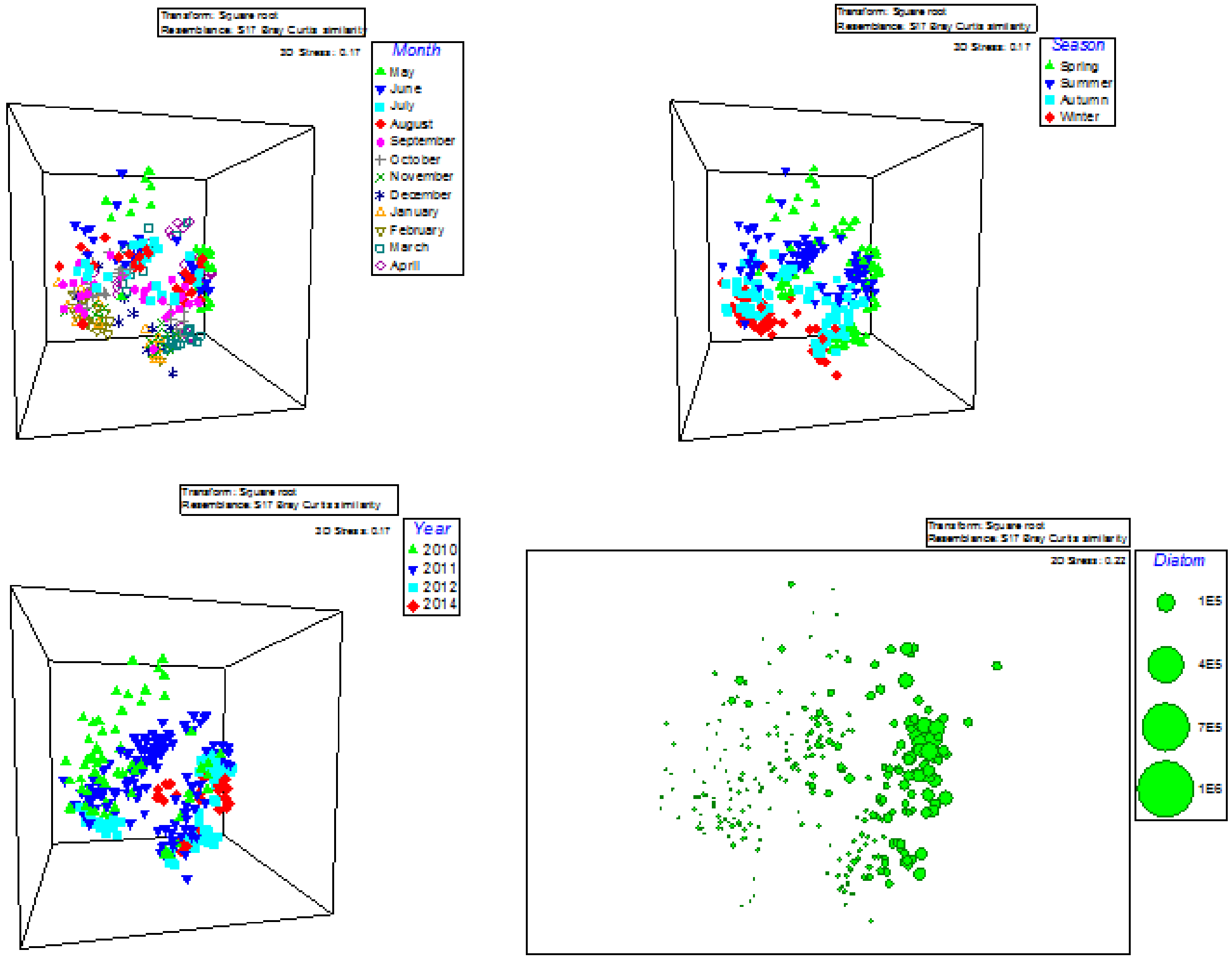


Figure 8.5 : 3-Dimensional MDS plots (stress 0.17) of phytoplankton whole community data between May 2010 and September 2014, displaying months (top left), seasons (top right) and years (bottom left), and 2-dimensional plot (stress 0.22) (bottom right) of the same data with diatom abundance superimposed as a bubble plot.

8.3.2 Pigment Analysis (HPLC)

ANOSIM analysis of the 2010 - 2012 pigment data indicated that there were no statistically significant differences in phytoplankton pigment distribution between sites (ANOSIM; Global R = 0.031, $p = 0.004$) or tidal states (ANOSIM; Global R = -0.026, $p = 1$). Therefore, as with phytoplankton taxa composition, all samples taken during each monthly survey have been considered as replicates for that specific month.

8.3.2.1 General Observations

All HPLC and 2014 chl-a results are listed in Appendix K (Table K.4 and Table K.5). Thirteen pigments were detected in total. Of these, chl-a and fucoxanthin were present at the highest concentrations (max. monthly chl-a average concentration 2903 ng L^{-1} in 2010-2012 observed in May 2012; Figure 8.6) and in all samples between May 2010 and October 2012. Chl-a concentrations were higher in 2014, reaching a maximum monthly average concentration of 6400 ng L^{-1} in May 2014 (Figure 8.6).

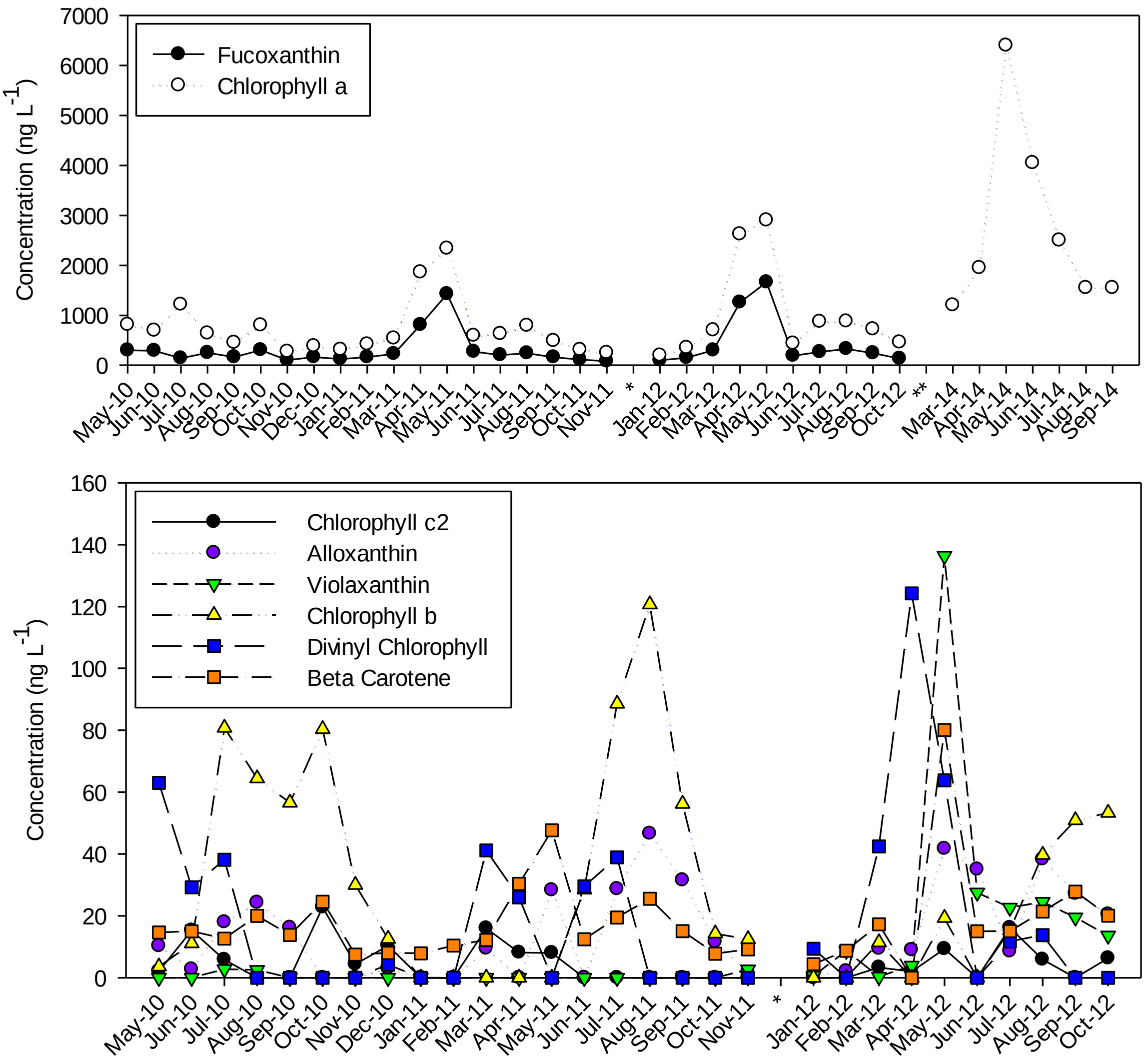


Figure 8.6 : Average monthly concentration of phytoplankton pigments. Pigment samples were not taken in December 2011 (*) or in 2013 (**). Only chl-*a* was sampled in 2014.

All other pigments were present at lower concentrations (max. monthly average concentration 136 ng L^{-1} in May 2012, Figure 8.6). Beta-carotene, alloxanthin, chlorophyll b and divinyl chlorophyll were present in at least a third of the samples, whereas the rest of the pigments occurred only occasionally over the 30-month period (May 2010-Oct 2012).

Fucoxanthin and chl-a concentrations peaked during the spring months, divinyl chlorophyll during the spring and summer months and chlorophyll b during the summer and autumn months (Figure 8.6).

8.3.2.2 Statistical Analysis

Only the 2010-2012 data were used in statistical analysis as in 2014, only chl-a was sampled. Overall, 51% of the variation in the data was explained by the first two axes of the PCA ordination (Appendix K, Table K.6 and Figure 8.7). The first axis (PC1) was clearly dominated by chlorophyll b to which it was negatively correlated (eigenvector = -0.806), and the second axis (PC2) by divinyl chlorophyll to which it was positively correlated (eigenvector = 0.790). This suggests that despite the fact fucoxanthin and chl-a were the most abundant pigments, they were not responsible for differences within the data. This could be due to these two pigments being ubiquitous in the samples. Where differences occurred, they appeared to be mainly the result of temporal changes in chlorophyll b(chl-b) and divinyl chlorophyll. The third PCA axis (perpendicular to PC1 and PC2) explained an additional 11% of variation in the data and was positively correlated to alloxanthin (Appendix K,Table K.6 and Figure 8.7).

The winter months were largely clustered at the bottom of the ordination indicating low levels of both chlorophyll b and divinyl chlorophyll, with little variation between samples (Figure 8.7 - Figure 8.9).

During March and April the levels of divinyl chlorophyll increased dramatically and high concentrations were sustained into the summer months June and July. Chl-b levels started to increase in May and continued to increase during summer (Figure 8.7 - Figure 8.9).

By August there was a pronounced change with a dramatic decrease in divinyl chlorophyll, while chl-b remained high. The clustering of sites from August, September, October and November within the bottom left of the plot suggests this trend remained consistent from late summer through to autumn. It was not until winter (December) that levels of chl-b declined significantly (Figure 8.7 - Figure 8.9).

Alloxanthin gradually increased in spring and peaked in summer and autumn before declining in late autumn and winter (Figure 8.10).

This analysis suggests that the temporal changes throughout each year can be broadly summarised into four phases (Table 8.2), albeit with some degree of overlap during spring and early summer.

Table 8.2 : Classification of monthly temporal trends as defined by varying levels of chlorophyll b and divinyl chlorophyll

Chlorophyll b	Divinyl Chlorophyll	Alloxanthin	Months
Low	Low	Low	December, January, February, March, April
Low	High	High	March, April, May, June
High	High	High	June, July
High	Low	High	August, September, October, November

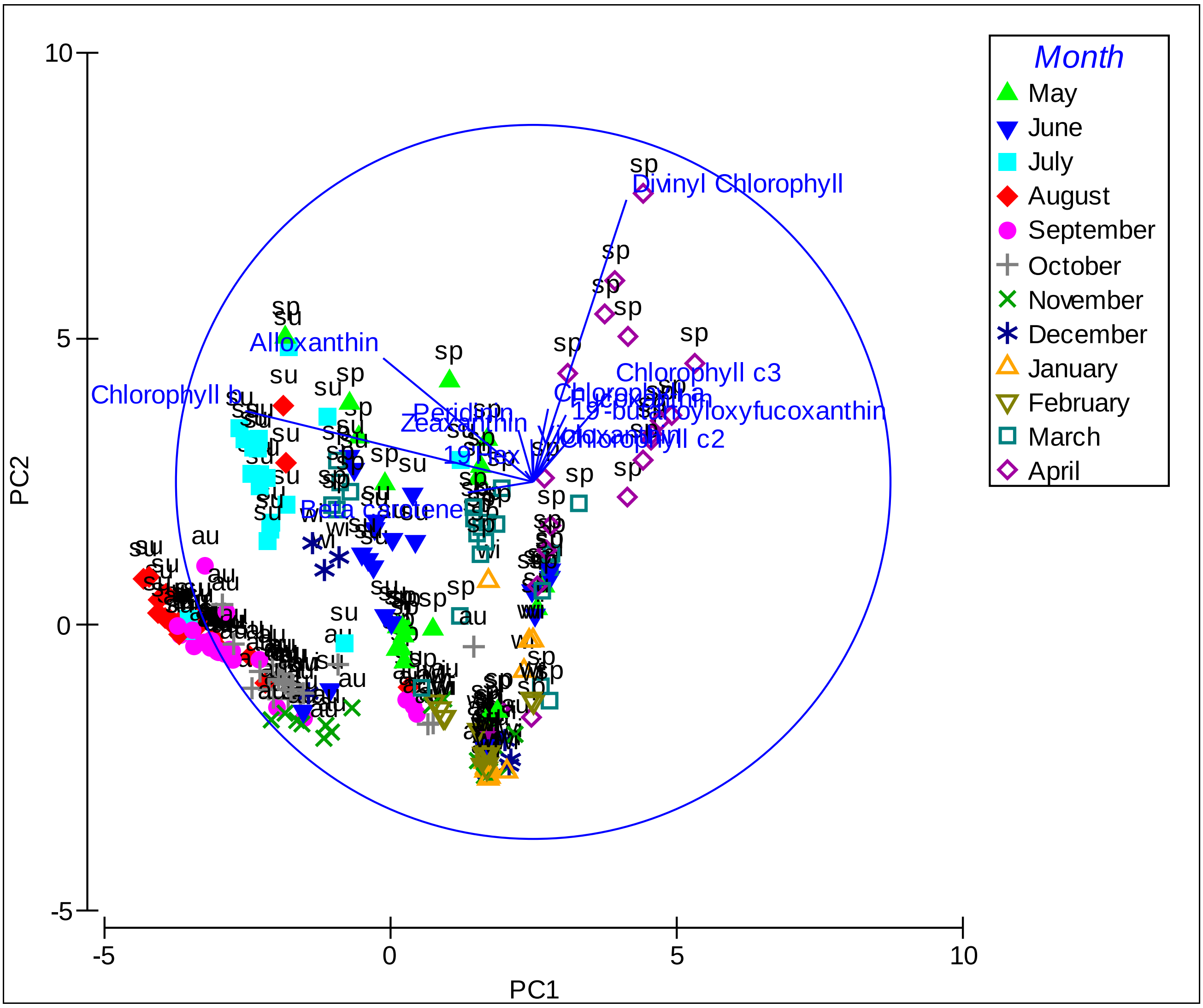


Figure 8.7 : PCA plot of phytoplankton pigment data displaying survey months as a factor. Seasons are displayed as labels (sp = spring, su = summer, au = autumn, wi = winter).

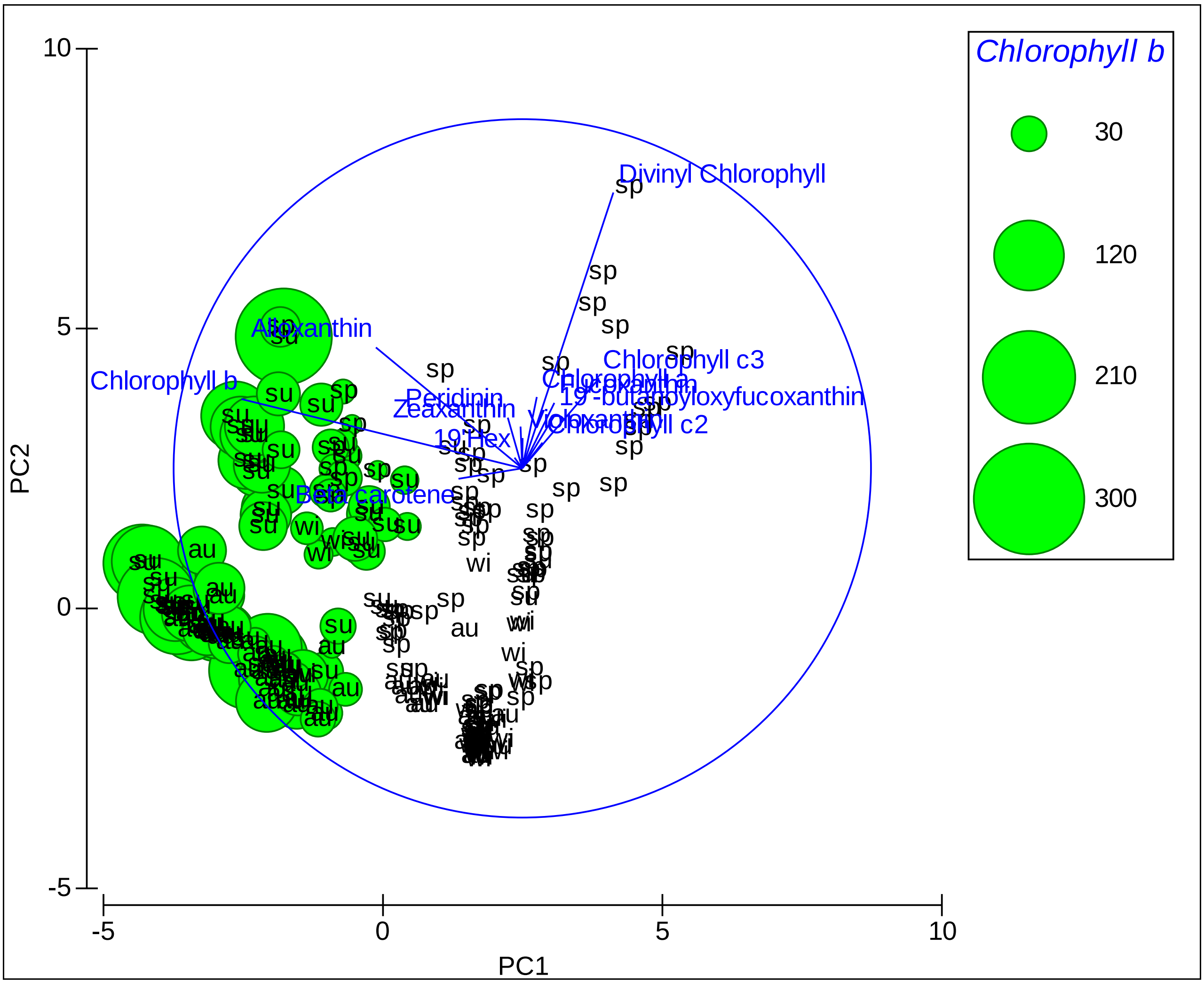


Figure 8.8 : PCA plot of phytoplankton pigment data with superimposed bubble plot displaying chlorophyll b concentration. Seasons are displayed as labels (sp = spring, su = summer, au = autumn, wi = winter).

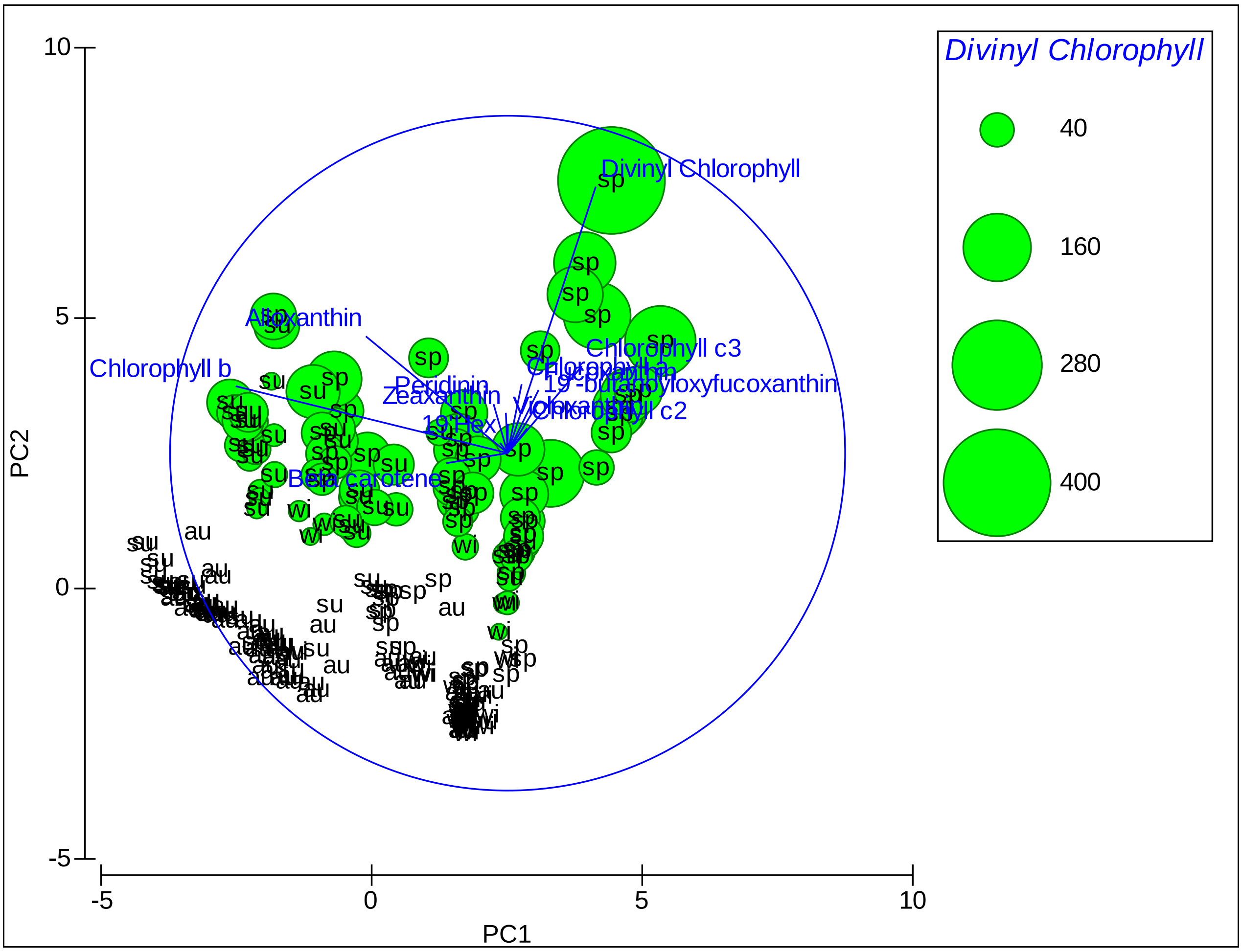


Figure 8.9 : PCA plot of phytoplankton pigment data with superimposed bubble plot displaying divinyl chlorophyll concentration. Seasons are displayed as labels (sp = spring, su = summer, au = autumn, wi = winter).

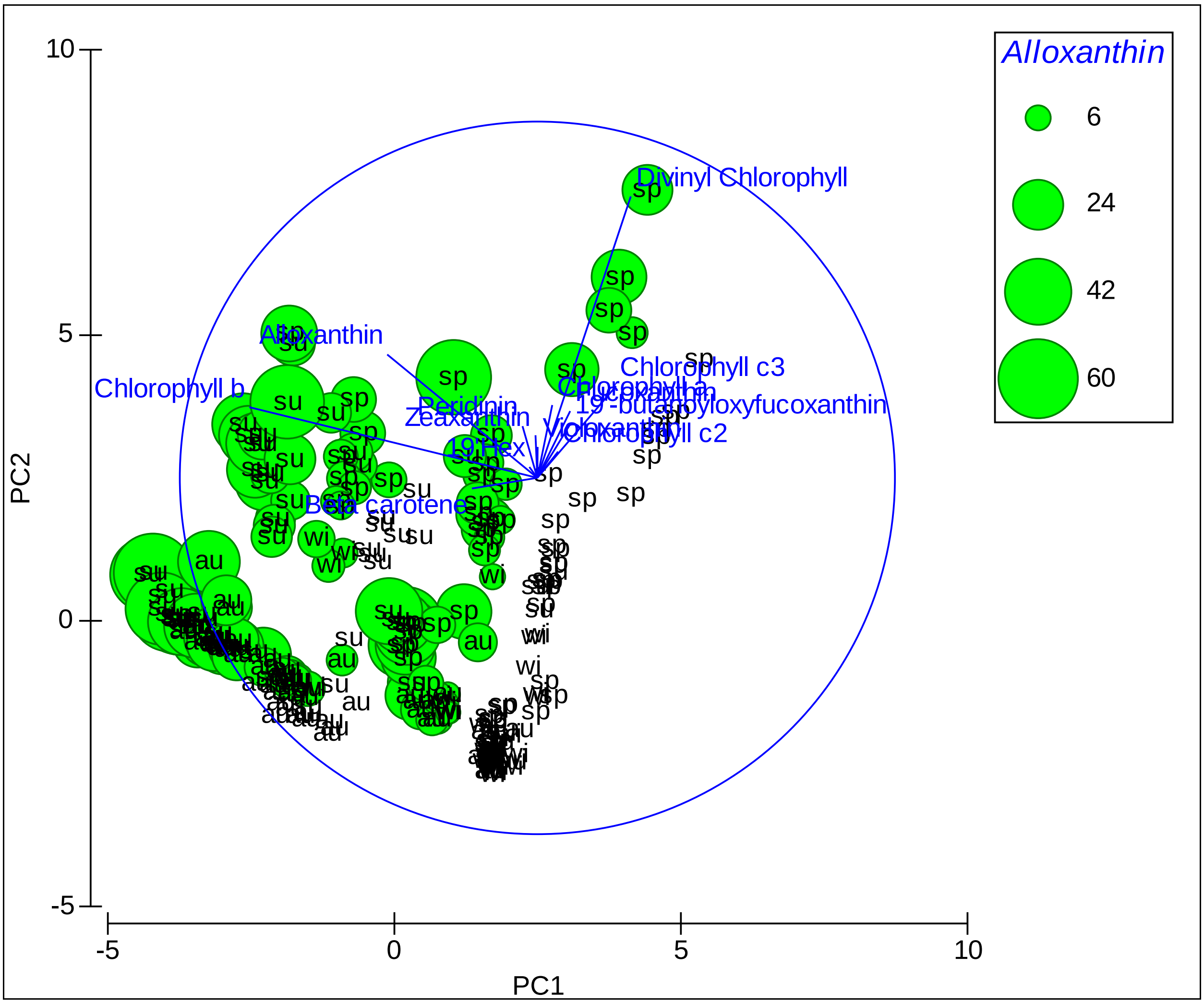


Figure 8.10 : PCA plot of phytoplankton pigment data with superimposed bubble plot displaying alloxanthin concentration. Seasons are displayed as labels (sp = spring, su = summer, au = autumn, wi = winter).

The seasonal patterns described above are supported by the results of ANOSIM analyses. Significant differences were found between months and seasons, although with a degree of overlap, and small differences between the same seasons of different monitoring years (Table 8.3). Pairwise comparisons indicated significant but small differences between the same seasons of 2010 and 2011 (R = 0.163, p = 0.001), however, larger significant differences were found between years 2010 and 2012 (R = 0.465, p = 0.001) and years 2011 and 2012 (R = 0.535, p = 0.001). These differences are most likely the result of only one site sampled during the majority of year 2012.

Table 8.3 : Results of ANOSIM analysis to assess whether measured phytoplankton pigments differed significantly between sites, tides, seasons, months and years.

Factor	ANOSIM type	Global R	P-value
Site	One-way	0.031	0.004
Tide	One-way	-0.026	1
Month	One-way	0.445	0.001
Season (across the same year)	Two-way crossed	0.432	0.001
Year (across the same seasons)	Two-way crossed	0.272	0.001

8.4 Discussion

The results presented in this report suggest there was little difference in the phytoplankton abundance and community composition between tidal states and between the different sites sampled along the north Anglesey coast.

Changes both in phytoplankton abundance and community composition exhibited, as expected, seasonality driven by changes in the light and nutrient regime in the water column. Seasonal changes in phytoplankton observed during the monitoring period were similar to those reported in other studies. The start of the phytoplankton production period in the Irish Sea is characterised by a spring bloom with a peak between March and May (Gowen and Stewart, 2005; Gowen *et al*., 2008); in this study a slightly later peak in abundance has been observed off north Anglesey (in May/June). However, maximum phytoplankton abundance during spring and summer (typically up to approximately 81,000 cells L^{-1}, with a maximum of around 300,000 cells L^{-1} on one occasion only in April 2012) was much lower than that observed in the north-east Irish Sea (>800,000 cells L^{-1}; Kennington *et al*., 1999) and Liverpool Bay (>10 million cells L^{-1}; Gowen *et al*., 2000). The maximum phytoplankton abundances reported during the monitoring period do not indicate bloom concentrations under WFD (bloom threshold $>10^6$ cells L^{-1}).

Low phytoplankton abundance was also mirrored in the low chl-a concentrations observed during the monitoring period; average values during the spring peak in abundance did not exceed 6.4 mg m^{-3} (max. 8.2 mg m^{-3}). Chl-a values were also below the indicator value for chl-a bloom under WFD (bloom threshold >10 µg L^{-1} or mg m^{-3}). These values are particularly low compared to Liverpool Bay (up to 43.9 mg m^{-3} during 2003 – 2005) and western Irish Sea (up to 15 – 20 mg m^{-3} during 1992 – 2004) (Gowen *et al*., 2008). However, reported values for the eastern Irish Sea were also quite low (up to around 6 mg m^{-3} during 2001 – 2003) (Gowen *et al*., 2008). Liverpool Bay is considered to be the most productive region of the Irish Sea, due to the nutrient-rich freshwater inputs from the Conwy, Dee, Mersey and Ribble estuaries (DEFRA, 2000), and phytoplankton blooms are a regular occurrence in this region (CMACS, 2006). The timing of these blooms is dependent on underwater light, climate and turbulent mixing (Greenwood *et al*., 2011). The north Anglesey coast is outside the influence of this nutrient-rich freshwater plume, and the nutrient data do not suggest nutrient enrichment (see Sections 3.3.2.3 and 3.4 for nutrient values) hence it was not expected to encounter phytoplankton densities as high as in other areas of the Irish Sea.

Diatoms were the most abundant phytoplankton group for the majority of the monitoring period. They generally dominated the spring phytoplankton peak abundance in all four years of the monitoring programme, in agreement with other observations from the Irish Sea (Gowen and Stewart, 2005). However, other groups such as microflagellates can represent an important component of the spring bloom (e.g. in 1997; Gowen and Stewart, 2005) and have numerically dominated the spring bloom in the past (e.g. in 2001; Gowen and Stewart, 2005). This was also observed in May 2010, when *Phaeocystis globosa* contributed the same as diatoms (38%) to the total phytoplankton abundance, and also in April 2012 when microflagellates were observed in very high abundances, dominating the spring phytoplankton peak abundance.

The high abundance of prymnesiophytes, predominantly *P. globosa*, in May 2010 (average around 2200 cells L^{-1}) preceded the phytoplankton abundance peak in June 2010, which was dominated by diatoms. A similar seasonal succession from prymnesiophytes to diatoms was observed in Liverpool Bay in 1997 (Gowen *et al*., 2000), although prymnesiophytes and other microflagellates reached bloom densities of up to 10×10^6 cells L^{-1}, which were not observed in this monitoring programme. The *P. globosa* densities did not indicate a bloom (defined as >5 colonies mL^{-1} in Gowen *et al*., 2008 and $>10^6$ cells L^{-1} in WFD) and this species was detected by microscopy at high densities only in May 2010. However, HPLC analysis showed presence of the pigment 19'Hex which is an indicator pigment of prymnesiophytes, with peak concentrations observed in October 2010 and October 2012 (Figure 8.11).

The taxa most important in describing differences between seasonal groups of samples were those taxa that contributed the most to total phytoplankton abundance. The diatom *Guinardia* (*G. delicatula* and *G. flaccida*) was the most abundant genus during spring in agreement with data from Liverpool Bay and Irish coastal waters (Gowen *et al*., 2000). The only exception to this was spring 2010 which was dominated by *Rhizosolenia* spp. Although not speciated, it is considered that this taxon likely consisted of the species *Rhizosolenia delicatula* and/or *Rhizosolenia flaccida*, which have since changed names to *Guinardia delicatula* and *Guinardia flaccida*, respectively. Hence it is considered that the same species have in fact dominated the spring abundances over the course of this study. Other dominant genera reported in this study such as *Chaetoceros*, *Skeletonema, Pseudo-nitzschia*, *Thalassiosira, Leptocylindrus* and *Cerataulina*, have been recorded as abundant during spring blooms elsewhere in the Irish Sea (Gowen and Stewart, 2005 and references therein), e.g. Liverpool Bay (DEFRA, 2000; Gowen *et al*., 2000), the Irish coastal waters (Gowen *et al*., 2000) and the north-east Irish Sea (Kennington *et al*., 1999). Phytoplankton data during winter are limited and hence the dominance of the diatom *Paralia* observed in this survey could not be compared against other studies.

During the monitoring period, 11 nuisance/harmful and 12 toxic algal species were reported at the sampling locations (Table 8.4). Some phytoplankton produce toxins that are harmful to marine fauna such as shellfish and fish, and also to humans if affected fauna are consumed, whereas nuisance species might cause mechanical damage such as gill clogging, production of foam, anoxia etc. The split between nuisance and toxic algae is not very clear as a few species can co-occur during red tides or other harmful/toxic events, sometimes making it hard to attribute the harmful effects to only one species. Ongoing research might provide further confirmation for the harmful effects of some ambiguous species. Of the nuisance or potentially harmful algae, *Phaeocystis globosa* reached high abundances of up to 6,000 cells L^{-1} during May 2010, while *Chaetoceros danicus* was recorded at densities of up to 2,320 cells L^{-1} in September 2014 and *Heterocapsa* sp. reached up to 2,400 cells L^{-1} in June 2010. Of the toxic algae, *Karenia mikimotoi* reached 9,320 cells L^{-1} in March 2012; *Pseudo-nitzschia delicatissima* reached up to 5,080 cells L^{-1} in May 2014 and *Pseudo-nitzschia seriata* up to 4,080 cells L^{-1} in June 2014. *Protoperidinium* spp. densities reached 1,440 cells L^{-1} in June 2012. The rest of the harmful/toxic species did not exceed 1,000 cells L^{-1} in any of the samples. These cell densities are considered very low compared to the abundance at which an individual taxon is considered to reach bloom densities (>250,000 cells L^{-1}).

Table 8.4 : List of nuisance/harmful and toxic algae identified off north Anglesey between May 2010 and September 2014.

Nuisance/harmful	Toxic
Akashiwo sanguinea	*Alexandrium* sp.*
Amphidinium spp.*	*Dinophysis acuminata**
Chaetoceros (Phaeoceros) spp.	*Dinophysis acuta**
Chaetoceros danicus	*Gonyaulax* sp.*
Dictyocha fibula	*Gymnodinium* spp. (some species)*
Dictyocha speculum	*Karenia mikimotoi**
Heterocapsa spp.*	*Phalacroma rotundatum**
Noctiluca scintillans	*Prorocentrum lima**
Phaeocystis globosa *	*Prorocentrum minimum**
Prorocentrum gracile (potentially)	*Protoperidinium* spp.
Prorocentrum micans (potentially)	*Pseudo-nitzschia delicatissma* complex*
	Pseudo-nitzschia seriata complex*

*These species are listed in the IOC-UNESCO Taxonomic Reference List of Harmful Micro Algae (http://www.marinespecies.org/HAB/)

Fifteen of the harmful/toxic species were recorded at Site 6 (Figure 2.1).

The maximum abundance of *P. delicatissima* in May 2014 (5,080 cells L^{-1}) and of *P. seriata* in June 2014 (4,080 cells L^{-1}) was recorded at this site; although abundance of these species was quite similar at the other sites sampled. *Protoperidinium* spp. maximum abundance in June 2012 (1,440 cells L^{-1}) was also recorded at Site 6. All other harmful/toxic algae were recorded at abundances <1,000 cells L^{-1} at this site throughout the monitoring programme.

The heterotrophic dinoflagellate *Noctiluca scintillans* (Phylum Myzozoa) was only reported nine times in the phytoplankton samples with a maximum abundance of 120 cells L^{-1} recorded at Site 6 in June 2012. This species, which is usually sampled better by zooplankton nets due to its large size (<200 µm) was recorded in many of the zooplankton samples (see Section 9). The maximum abundance recorded in the zooplankton samples was also in June 2012, but did not exceed 4 cells L^{-1}. Blooms of this species have been linked to fish and invertebrate kills.

Most of the harmful/toxic species observed in this study have been reported in the Irish Sea since 1993 (Gowen and Stewart, 2005). Of the toxic species, *Gonyaulax* spp. (although many species under this genus are synonymised with *Alexandrium* spp.) and *P. rotundatum* have not been previously reported. Of the harmful taxa, *A. sanguinea*, *Amphidinium* spp., *D. fibula*, and *Heterocapsa* spp. have not been reported before under the 'harmful' umbrella in the Irish Sea but could well be listed in the phytoplankton species present but at low abundances.

Phaeocystis has regularly appeared in the Irish Sea, at least since the 1950s (Gowen and Stewart, 2005) and is responsible for the production of dense foam which can accumulate in coastal waters (DEFRA, 2000). *Pseudo-nitzschia* is believed to be responsible for the periodic closure of shellfish beds along the Irish coast (Gowen and Stewart, 2005; CMACS, 2006).

Two invasive non-native diatom species were recorded during the monitoring period: *Coscinodiscus wailesii* and *Odontella sinensis*. Only one cell (40 cells L^{-1}) of *C. wailesii* was recorded from the samples between 2010 and 2014 and specifically from Site 4 in December 2010. *O. sinensis* was recorded on 10 occasions in total and specifically in autumn 2011, winter 2012, May 2012 and May 2014. This species was found at several of the monitoring sites, including Porth-y-pistyll, but at very low abundances of 40 – 160 cells L^{-1}. Both of these diatoms are well established in British and European waters. *C. wailesii* can have an economic impact when reaching high numbers, as result of the mucilage produced clogging fishing gear (Eno *et al*., 1997).

Table 8.5 summarises the pigments found in different phytoplankton groups as listed in Llewellyn *et al*. (2005) and Goericke and Repeta (1992). Apart from chl-a which is a universal pigment found in all phytoplankton groups, fucoxanthin and chl-b were the indicator pigments with the highest average monthly concentrations. Indicator pigments are those found in only one or a few groups and hence are characteristic of these, unlike for example chl-a and beta-carotene.

Chl-a concentrations co-varied with total phytoplankton abundance (Figure 8.11). However, higher chl-a concentrations were observed in spring 2012 and spring 2014 than in spring 2011, even though total phytoplankton abundance in spring 2011 was much higher. This is not surprising as cellular pigment content can vary up to a factor of 10 in environments where phytoplankton growth might be limited by light or nutrient conditions (Goericke and Repeta, 1992). A similar trend was seen in both diatom distribution and their indicator pigment, fucoxanthin (Figure 8.11), and in the distribution of the dinoflagellates and the pigment peridinin (Figure 8.11).

Other phytoplankton groups did not show as close a relationship with their indicator pigments (Figure 8.11). *Prymnesiophytes* were scarcely detected in the samples except for May 2010, however, the presence of 19'Hex in autumn 2010 and summer - autumn 2012 suggests the opposite. Similarly, chl-b and alloxanthin distributions suggested the presence of euglenophytes and chlorophytes as well as cryptophytes during the spring and summer seasons of all three years, whereas these groups were not detected in high numbers by light microscopy. All of these groups are difficult to identify by light microscopy due to the small size of the cells and hence may have been missed during microscopy enumeration.

Finally, divinyl chlorophyll was found in the samples and showed seasonality with high concentration in spring and summer and low concentrations in autumn and winter. This pigment is an indicator pigment for prochlorophytes which cannot be detected by use of light microscopy due to the small size of the cells and need the use of epifluorescence microscopy or flow cytometry to be detected. Hence, HPLC analysis has revealed the existence of a taxonomic group that would not have been detected with the microscopy analysis. Therefore, the combination of both light microscopy and HPLC analysis should ideally be used for monitoring of phytoplankton populations, as the two methods complement each other and give the maximum amount of information possible for phytoplankton assemblage composition.

In conclusion, there were no differences in phytoplankton abundance or composition between the sites monitored and any changes observed could be attributed to seasonal and year-on-year variation. The phytoplankton community composition off north Anglesey is considered usual for this part of the Irish Sea, although abundance is generally low most probably due to the low nutrient concentrations compared to other areas. No bloom densities were reached under the WFD classification throughout the monitoring programme and any harmful/toxic algae present were recorded at very low densities and have largely been reported from the Irish Sea since the 1950s.

Table 8.5 : Phytoplankton groups and associated pigments (Llewellyn *et al*., 2005; Goericke and Repeta, 1992).

Phytoplankton groups	Chl-*a*	Divinyl chl	Fucoxanthin	Peridinin	Alloxanthin	Chl-*b*	Chl-c_2	Chl-c_3	Beta carotene	Zeaxanthin	Violaxanthin	19'Hex
Diatoms	+		+				+	+	+			
Dinoflagellates	+			+			+		+			
Prymnesiophytes	+		+				+	+	+			+
Chrysophytes	+		+						+			
Cryptophytes	+				+		+		+			
Cyanophytes	+									+		
Chlorophytes	+					+			+	+	+	
Euglenophytes	+					+			+	+		

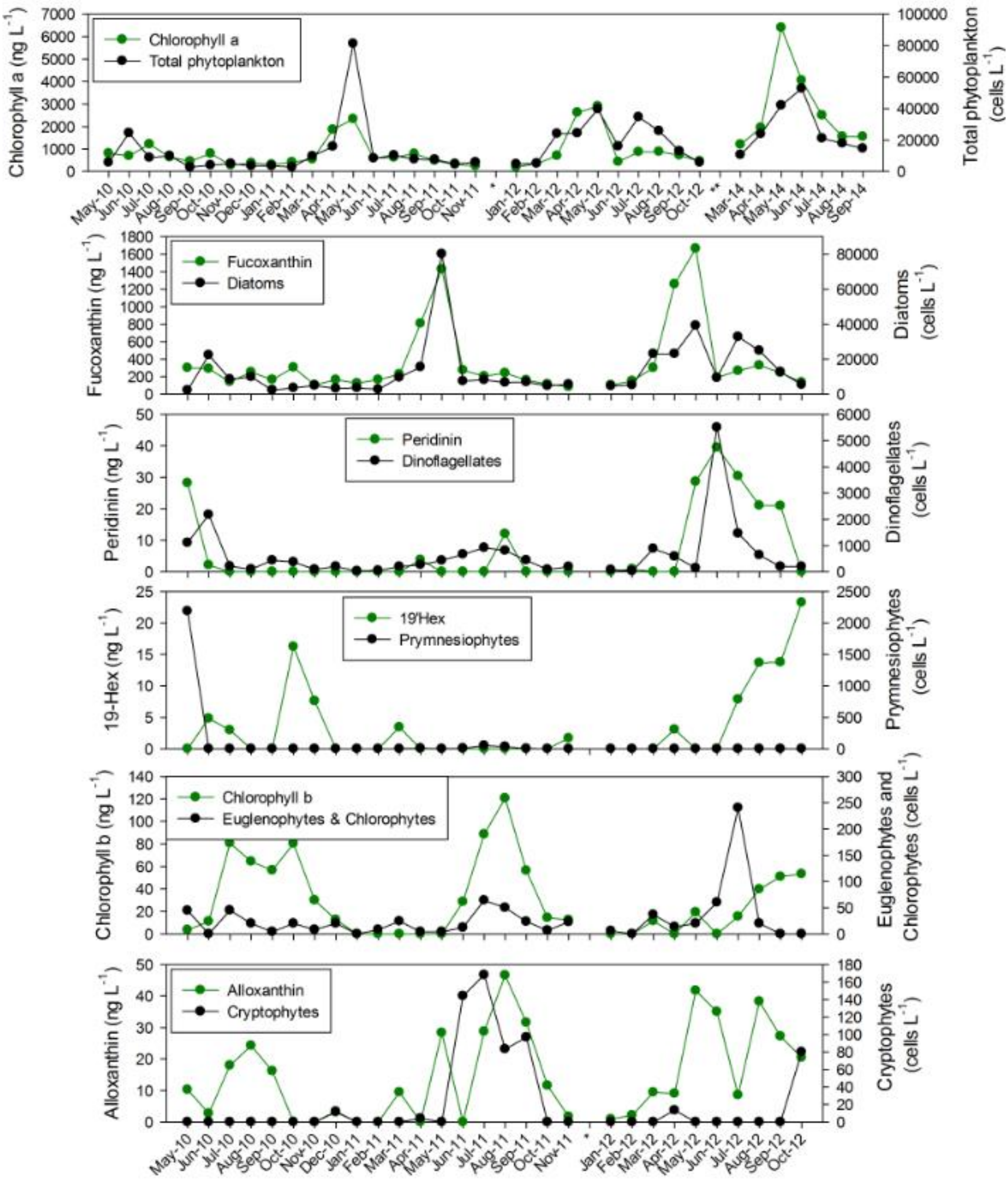


Figure 8.11 : Monthly variation in phytoplankton groups and their indicator pigments from sites along the north Anglesey coast. Total phytoplankton is excluding microflagellates.

9. Zooplankton

9.1 Introduction

This section presents the results of the zooplankton surveys carried out between May 2010 and June 2014, encompassing:

- two full years of the monitoring programme (May 2010 – April 2012) for the original five sampling sites (Sites 1 to 5[11]);
- 14 months of data (August 2011 – October 2012) for Site 6 only, which was located within 500 m of the CW intake proposed location at Porth-y-pistyll; and
- four months of data (March – June 2014) for the revised sampling sites (Sites 2, 4, 6 and 7); Site 7 was located in Cemlyn Bay, just west of Porth-y-pistyll.

Sampling was carried out on a monthly basis between 2010 and 2013 at sites during neap and spring tidal cycles, and over flood and ebb tides. During the 2014 programme, a reduced number of sites were sampled, and these were carried out on any state of tide (flood, ebb or slack tide).

9.2 Methods

9.2.1 Survey Methodology

As with the water quality and phytoplankton work, surveys took place on board the vessel 'SeeKat C' and followed methods agreed with key stakeholders and statutory regulators prior to implementation of the programme. The locations of the sample sites were identical to those of the water quality and phytoplankton monitoring, as previously detailed in Section 2.

9.2.2 Sampling Methodology

Zooplankton samples were collected each month with an interval of at least ten days between sampling at all sites.

The choice of methods used in these surveys was agreed with statutory regulators and in the absence of WFD or UKTAG guidance for zooplankton monitoring, one sample at each site was collected using a 250 µm conical mesh net with a top diameter of approximately 31 cm, filtering at least 200 L of seawater.

A clean weighted net was lowered to a depth between 8 and 10 m and lifted vertically through the water to the surface at a rate of approximately 0.3 m s^{-1}. The sample was rinsed thoroughly down into the cod end with filtered seawater, this was then removed and washed into a 250 mL PET bottle and fixed to a 4% formaldehyde concentration. Each sample was labelled with the type of sample, the date, tidal state (flood, ebb (or slack in 2014)) and site number and stored at the Jacobs Southampton Laboratory ready for analysis.

9.2.3 Sample Analysis

Each sample was filtered through gauze with a mesh size of 125 µm to compensate for the likely shrinkage of organisms caused by formaldehyde preservation. The sample was then rinsed thoroughly with water and transferred to a petri dish for analysis.

Samples were analysed to the lowest taxonomic resolution practicably possible using a stereomicroscope with both a backlight and a main light. Switching to a black background can sometimes show up features more clearly.

[11] All sampling sites are coincident with those of the WQ survey and are numbered the same. However, the prefix WQ has been removed.

Where samples were small (<200 individuals) identification and counting of the whole sample used a tally or clicker-counter system. Where samples contained a high number of individuals (generally >350), sub-sampling using the method described below was carried out.

The genus *Noctiluca* is a dinoflagellate (i.e. phytoplankton); however, like many other dinoflagellates it is heterotrophic and does not photosynthesize and due to its large size, is often counted within zooplankton samples (D. Conway pers. comm., July 2007) and (Elangovan *et al*., 2010).

9.2.3.1 (i) Sub-sampling

Before sub-sampling was carried out, initial counts and total numbers of any large or singular species that may be misrepresented through sub-sampling were made (i.e. large individuals such as adult *Calanus* spp. and mysids or singular individuals). These individuals were then taken out prior to sub-sampling and added to the species list after all multiplications had been completed.

For sub-sampling, the sample was washed into a marked glass jar and filled with water to a known volume (e.g. 250 mL - with both 250 and 125 mL levels marked). Using another identical marked glass jar, the sample was mixed between the two jars, pouring from one to the other repeatedly. This method provides an unbiased subsample and is the preferred method employed at the Plymouth Marine Laboratory (D. Conway pers. comm., July 2007).

Once the sample was well-mixed (approximately 40 separate pours), half the sample was quickly poured into one jar in a swift motion stopping at the 125 mL mark. When necessary, this halved sample was split to a quarter by refilling with water to the 250 mL mark and repeating the above process.

The total numbers and identity of the individuals from the proportion sub-sampled were then recorded, ensuring that the values obtained during the initial count were added.

9.2.4 Data Analysis

As part of the analysis of results, multivariate statistical tests were performed using PRIMER 6TM (Clarke and Gorley, 2006).

9.2.4.1 Community Analysis

The community analysis used a multivariate approach, where each taxonomic level (e.g. phylum; see Appendix L Table L.1 for a taxonomic list) was treated as a separate variable, enabling an assessment of complex patterns within large datasets. The multivariate analysis compared differences between all species (and each of the other taxonomic levels) and their relative abundances between samples and sites. The analysis allowed identification of samples with similar communities.

All data were square root transformed to remove skew and down-weight the influence of numerically dominant taxa. Similarity matrices were created based on Bray-Curtis similarity which is suitable for biotic data (Clarke and Gorley, 2006).

A two-way crossed ANOSIM (analysis of similarity) for no replicates was used to test for differences between samples taken on the same survey, whereas a two-way crossed ANOSIM was used to compare seasons and monitoring years. The two-way crossed ANOSIM only compares similarities between samples within the same level of the second factor, therefore it is appropriate to use when there is need to separate seasonal from spatial variation or seasonal from year-on-year variation (i.e. to identify any difference in the same season from year to year and any differences between seasons of the same year). This approach can be viewed as a non-parametric version of a multivariate ANOVA (MANOVA) (Clarke and Gorley, 2006). A one-way ANOSIM was used to test for differences between months or monitoring years. The ANOSIM was carried out on Bray-Curtis matrices of the different taxonomic levels, with 999 permutations, using season (spring, summer, autumn, winter), monitoring years (1 to 5), sites and tide as factors.

To further investigate and visualise differences in communities across factors (months, seasons, monitoring years), non-metric Multidimensional Scaling (MDS) (25 restarts, Kruskal fit) was carried out on the Bray-Curtis similarity matrix. MDS constructs a sample 'map' whose distances reflect statistically tested 'true' differences between the sites. Put simply, the closer a sample is to another sample on the ordination plot the more similar the samples are to each other.

Where ANOSIM found significant differences, a SIMPER test was used to investigate which individual taxa were driving the Bray-Curtis similarity within groups and dissimilarity between these groups. The test ranks, in order of importance, each taxon by calculating their overall percentage contribution to the average dissimilarity between each group. The Bray-Curtis similarity (or dissimilarity) coefficient (S') takes values between 0 (total dissimilarity) and 100% (total similarity).

In addition to the multivariate analysis, univariate data analysis which concentrated complex ecological data into a single metric, such as Shannon-Wiener diversity (H'), was also performed.

The average species (or taxa) richness (S) and Shannon-Wiener diversity index (H') were calculated for Arthropoda for each survey month. Species or taxa richness is simply the total number of species (or taxa) whereas Shannon-Wiener diversity provides a measure of species/taxa diversity by incorporating both species richness and equitability components, i.e. how evenly the individuals are distributed among the different species/taxa. The value of Shannon-Wiener diversity is increased either by the addition of more species or by having a greater species evenness.

9.3 Results

This section describes the zooplankton community off north Anglesey from May 2010 through to June 2014. A two-way crossed ANOSIM analysis (no replicates) using site/tide and month/year as factors, indicated that there were no statistically significant differences in zooplankton community structure between samples taken at different sites and tidal states in any one survey (Global $R = 0.022$, $p = 0.104$). Therefore, all samples taken during each monthly survey have been considered as replicates for that specific month for the survey area.

Community analysis was considered in three different ways:

1) as a whole community;

2) as taxa within the phylum Arthropoda; and

3) as taxa within the sub-class Copepoda

Analysis was carried out in this manner due to the high contribution of Arthropoda and, in particular, the sub-class Copepoda to the total zooplankton abundance.

9.3.1 Community Analysis

A full taxonomic list of all zooplankton recorded can be found in Table L.1 with average abundances of the different phyla observed over the monitoring period (May 2010 to June 2014) displayed in Appendix L, Table L.2.

Table 9.1 lists the taxonomic phyla, classes and orders identified in the samples. A total of 18 phyla have been recorded off north Anglesey. Of these, Arthropoda (consisting of the classes Arachnida, Branchiopoda, Maxillopoda, Malacostraca and Ostracoda) occurred most frequently. In May 2010, July and August 2011 and June 2012 class Dinophyceae (Phlyum Myzozoa) dominated. For all other months the class that dominated the zooplankton samples in terms of abundance was Maxillopoda. This class was made up of subclasses Copepoda (orders Harpacticoida, Calanoida, Cyclopoida, Poecilostomatoida and Monstrilloida) which comprised on average more than 60% of the total zooplankton, and Thecostraca (order Sessilia) which comprised approximately 11% of the total zooplankton.

Table 9.1 : Zooplankton (in terms of phyla, class and order) recorded off north Anglesey between May 2010 and June 2014 inclusive. *Indicates the taxonomy for the heterotrophic dinoflagellate *Noctiluca* sp.

Phylum	Class	Order
Annelida	Actinopterygii	Amphipoda
Arthropoda	Anthozoa	Anthoathecata
Brachiopoda	Appendicularia	Aphragmophora
Bryozoa	Arachnida	Beroida
Chaetognatha	Ascidiacea	Calanoida
Chordata	Asteroidea	Clupeiformes
Cnidaria	Bivalvia	Copelata
Ctenophora	Branchiopoda	Cumacea
Echinodermata	Dinophyceae*	Cyclopoida
Foraminifera	Enteropneusta	Cydippida
Hemichordata	Gastropoda	Decapoda
Mollusca	Hydrozoa	Diplostraca
Myzozoa*	Malacostraca	Gadiformes
Nemertea	Maxillopoda	Harpacticoida
Ochrophyta	Nuda	Isopoda
Rotifera	Ophiuroidea	Leptothecata
Tardigrada	Ostracoda	Limnomedusae
Phoronida	Polychaeta	Littorinimorpha
	Sagittoidea	Lobata
	Scyphozoa	Monstrilloida
	Tentaculata	Mysida
	Holothuroidea	Mytiloida
	Branchiopoda	Noctilucales*
		Ophiurida
		Perciformes
		Phragmophora
		Phyllodocida
		Pleuronectiformes
		Podocopida
		Poecilostomatoida
		Sabellida
		Semaeostomeae
		Sessilia
		Siphonophorae
		Spionida
		Tanaidacea
		Apodida
		Euphausiacea

Phylum	Class	Order
		Terebellida
		Trachymedusae
		Trombidiformes

In terms of abundance the phylum Arthropoda was clearly dominant within the samples, representing more than 50% of the total zooplankton abundance on all but four sampling months (May 2010, July and August 2011 and June 2012), when the zooplankton samples were dominated by the heterotrophic dinoflagellate group Myzozoa (representing on average 65%), (Figure 9.1). Across all phyla, an average of 742 individuals m^{-3} were recorded each month over the whole sampling period with the highest average abundance recorded in April 2012 (4,509 individuals m^{-3}); during this month Arthropoda accounted for 75% (3,362 individuals m^{-3}) of the total average abundance. The phyla Annelida and Chordata also recorded their highest monthly abundance during April 2012 (600 and 466 individuals m^{-3} respectively).

The subclass Copepoda dominated the zooplankton community to such an extent (see above) that they were analysed separately (9.3.3) to determine if temporal patterns existed and understand how this group influenced the community.

Consideration of the zooplankton community after removal of the heavily dominant Copepoda allowed a clearer picture of how the other phyla contributed to the community (Figure 9.2). This showed that other than Arthropoda the phyla Annelida, Chordata, Mollusca and Bryozoa were also key contributors to the community assemblage. Of the other phyla, Bryozoa and Mollusca only occurred at certain times of the year (February through to May) at relatively high abundance, with highest abundances recorded during 2012.

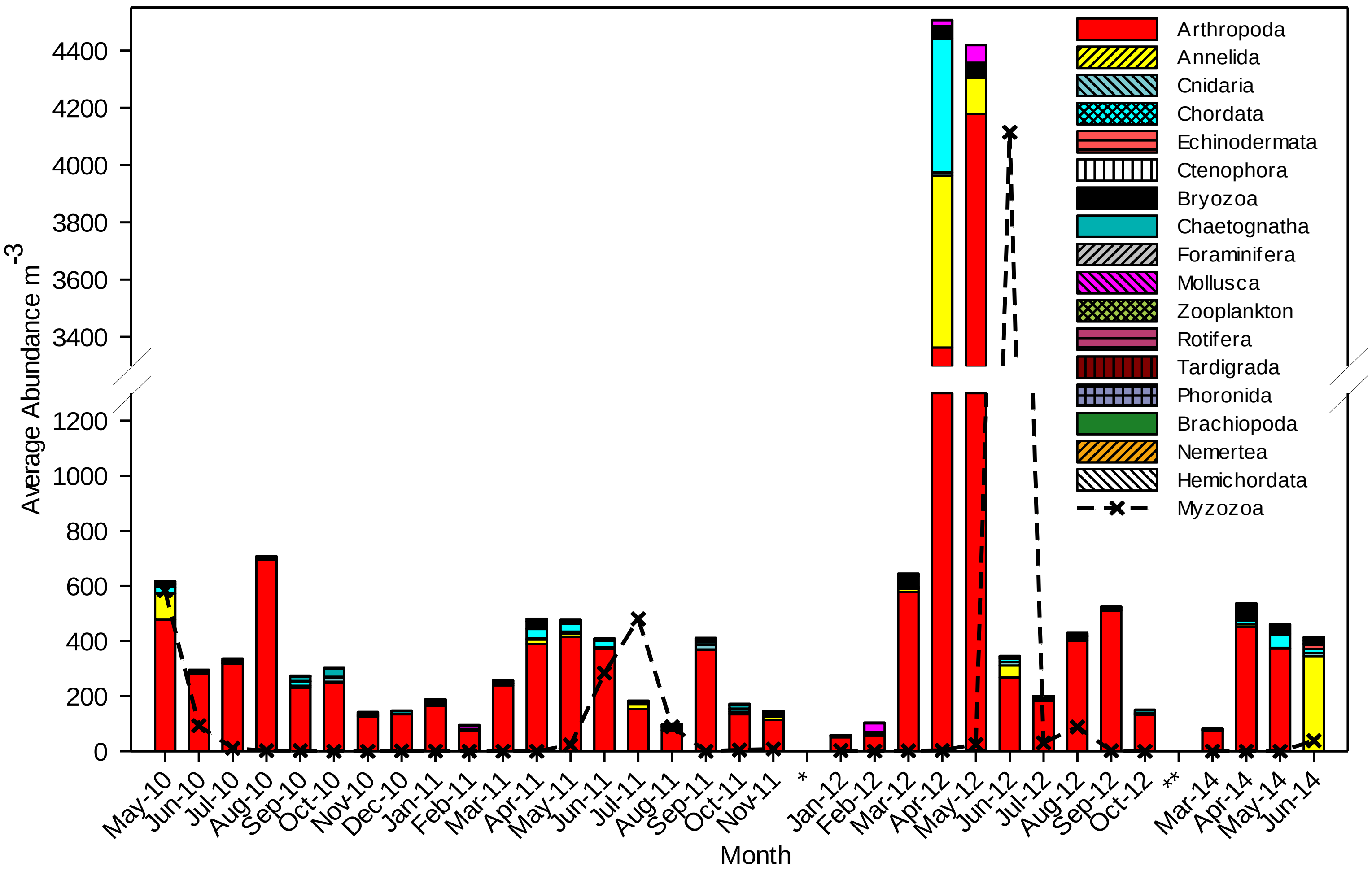


Figure 9.1 : Average abundance by phylum per month of all zooplankton recorded off north Anglesey between May 2010 and June 2014. Zooplankton samples were not taken in December 2011 (*) or in 2013 (**).

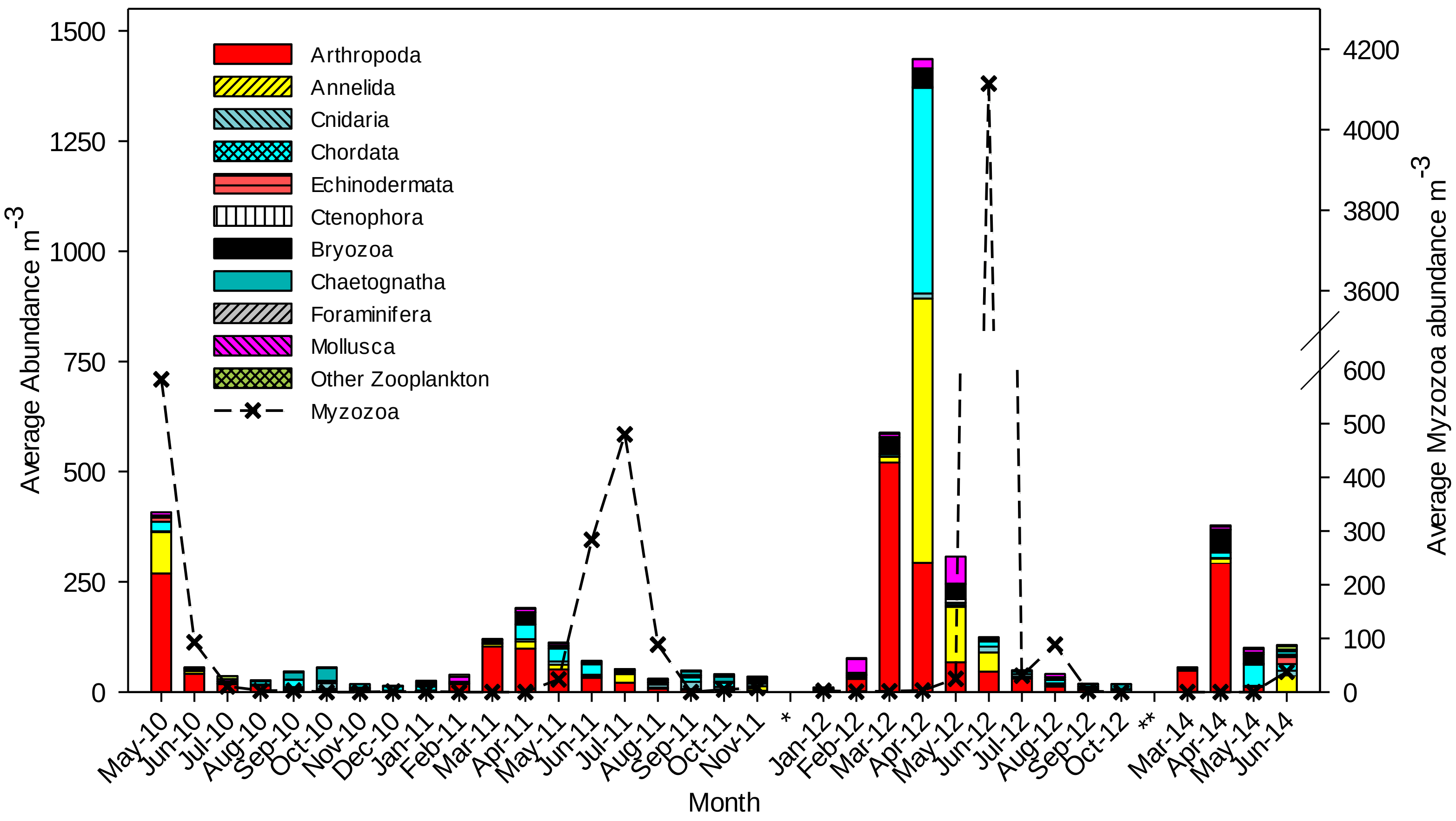


Figure 9.2 : Monthly average abundance of zooplankton classes contributing >5% to total zooplankton abundance (excluding Copepoda) between May 2010 and June 2014. Zooplankton samples were not taken in December 2011 (*) or in 2013 (**).

Considering the zooplankton community with respect to seasons since May 2010 (Figure 9.3), it is clear that the community composition was dominated by four key phyla during the spring months; these were Arthropoda, Annelida, Chordata and Myzozoa.

Throughout the remaining seasons, Arthropoda remained prevalent with Myzozoa peaking during the summer months. Other less prominent phyla were found in low abundances in certain seasons including Bryozoa and Mollusca during spring and Chaetognatha, Cnidaria and Chordata during autumn.

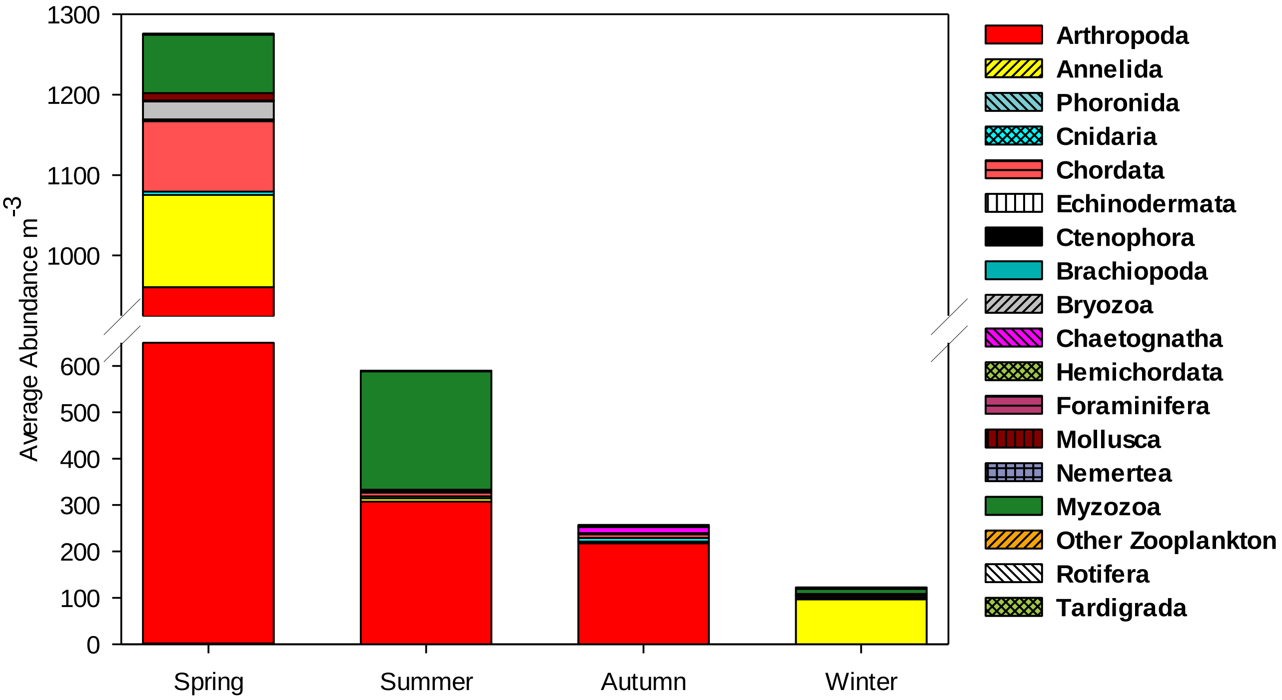


Figure 9.3 : Seasonal representation by phylum of all zooplankton recorded off north Anglesey between May 2010 and June 2014.

These observations are further supported by statistical analysis; a two-way crossed ANOSIM showed differences between seasons across all years (Global R = 0.697, p = 0.001). Table 9.2 shows high Global R values between all seasons and particularly between spring/autumn, summer/autumn and summer/winter, indicating the significant separation between these seasons, in terms of community composition. However, the same analysis showed that similar seasons differed significantly between years (Global R = 0.456, p = 0.001). The greatest differences were observed between years 2010 and 2011, and the smallest differences between years 2012 and 2014 (Table 9.3).

Table 9.2 : Pairwise comparisons between seasons across all years.

Groups	Global R	Significance Level (%)
Spring, Summer	0.593	0.1
Spring, Autumn	0.895	0.1
Spring, Winter	0.620	0.1
Summer, Autumn	0.728	0.1
Summer, Winter	0.744	0.1
Autumn, Winter	0.611	0.1

Table 9.3 : Pairwise comparisons between years across all seasons.

Groups (Monitoring Years)	R	Significance Level (%)
2010, 2011	0.54	0.1
2010, 2012	0.438	0.1
2010, 2014	0.497	0.1
2011, 2012	0.367	0.1
2011, 2014	0.417	0.1
2012, 2014	0.276	0.1

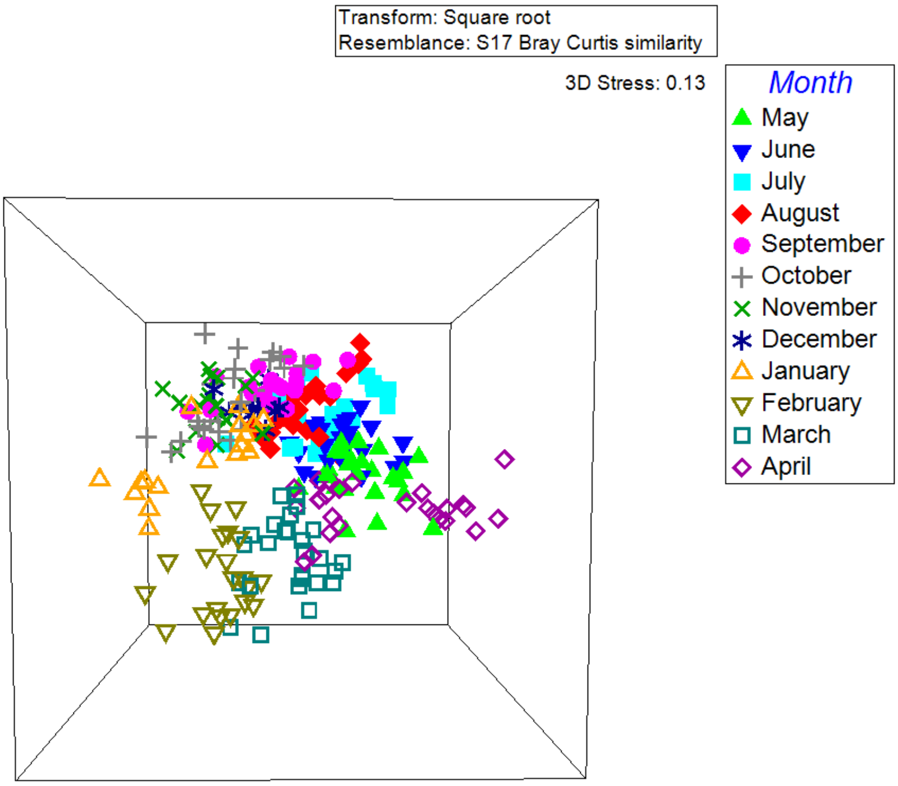
To further investigate the differences observed between similar seasons of different years, a two-way crossed SIMPER analysis was undertaken. The results (Appendix L, Table L.3) showed the driving factor for differences between year 2010 and other years to be the variation in abundance of the heterotrophic dinoflagellate *Noctiluca* sp. (phylum Myzozoa) and of a number of calanoid copepods (*Temora longicornis*, *Acartia* spp., *Centropages hamatus*, *Paracalanus parvus* and *Pseudocalanus elongatus*). Variation in abundance of the same calanoid copepods was also driving differences between other years (2011, 2012 and 2014). However, varying abundances of tunicates of the class Appendicularia also contributed significantly to differences when comparing years 2011 and 2012 to other years. Similarly, the barnacle larvae of the order Thoracica also contributed significantly to differences when comparing years 2012 and 2014 to other years.

Based on the SIMPER analysis groupings *T. longicornis* and *C. hamatus* were most abundant in 2012 and least abundant in 2011 and 2014, whereas *Noctiluca* sp. and *Acartia* spp. were more abundant in 2010 and least abundant in 2012 and 2014. Both Appendicularia and Thoracica abundance were highest in 2012 and lowest in 2010. These variations might seem in contrast to the abundances described in Figure 9.1 and Figure 9.2; this is because the abundances described in the SIMPER results are based on square root transformed data, downweighting the contribution of really abundant taxa such as *Noctiluca* sp.

A one-way ANOSIM analysis indicated that there was an overall statistically significant difference between months (Global R = 0.630, p = 0.001). Pairwise comparisons (Appendix L, Table L.4) showed that, as expected, small R values tended to occur between adjacent months e.g. October, November and November, December, and hence these months were thought to have relatively similar zooplankton communities.

This overlap between communities is clear when viewing the data as an MDS plot by observing the close association between samples from September through to December and samples from June through to August (Figure 9.4). This is further clarified in Figure 9.4 where seasons are clearly defined and regardless of the year are tightly clustered together.

Clear changes were identified in the zooplankton analysis between different seasons, indicating that the zooplankton community is driven predominantly by the varying environmental factors that constitute changes in season.



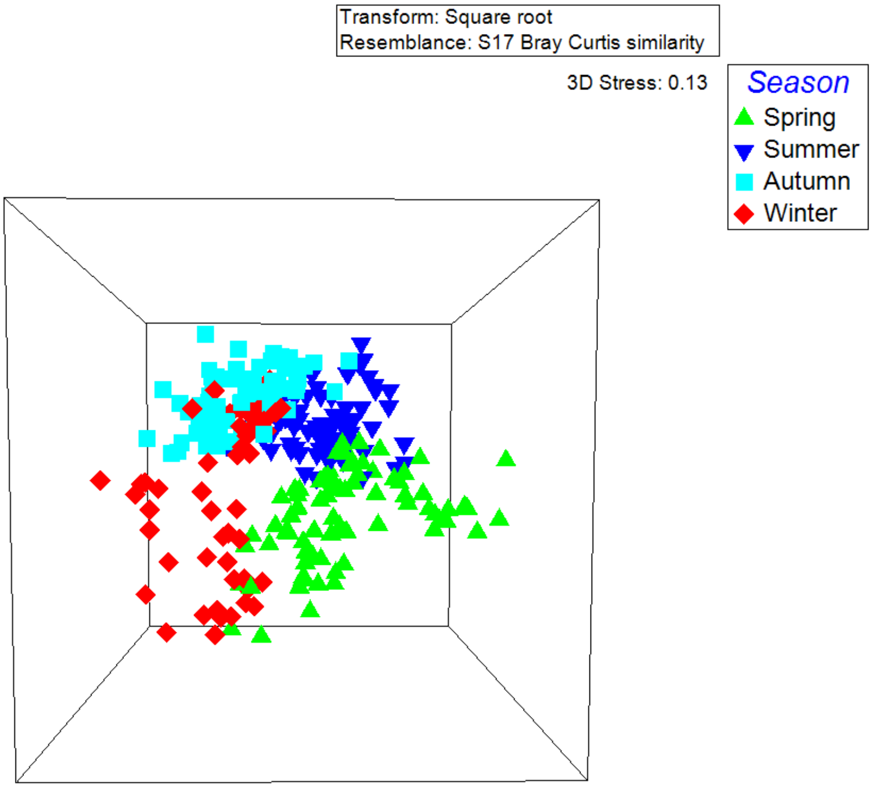


Figure 9.4 : 3D-MDS Plot of zooplankton whole community data between May 2010 and June 2014 displaying months (above) and seasons (below).

The two-way crossed SIMPER analysis was also consulted to determine which taxa were responsible for the differences observed between seasons across all years. The results (Appendix L, Table L.5) showed the driving factor to be the variation in seasonal abundance of a number of key taxa belonging to four different phyla.

Species such as *T. longicornis* and *Centropages hamatus* (phylum Arthropoda) contributed to the dissimilarity between seasons with high abundances in spring and summer against correspondingly low abundances in autumn and winter. Moreover, high abundances of *Noctiluca* sp. (phylum Myzozoa) and *Acartia* sp. (phylum Arthropoda) during summer and *Thoracica nauplius* (phylum Arthropoda) during spring, contributed to differences between these and other seasons. Additionally, the abundance of the copepods *Paracalanus parvus* and *Pseudocalanus elongatus* were generally higher in autumn and winter than in spring and summer which contributed to the dissimilarity observed between these seasons.

9.3.2 Arthropoda Richness and Diversity

Over the monitoring period (May 2010 to June 2014), Arthropoda constituted 65% of total zooplankton abundance. Due to this overall dominance of Arthropoda, further analysis has been carried out on data including this group only. Taxa richness and the Shannon-Wiener diversity index (H') were calculated for the phylum Arthropoda and plotted in Figure 9.5 for all months between May 2010 and October 2012 as well as for the samples collected between March 2014 and June 2014.

In general, there were a greater number of taxa present during the spring and summer months than in the winter months. Taxa richness (S) was highest in June 2010, June 2011, August 2012 and June 2014 with a taxa richness ranging between 14 and 18. Shannon-Wiener diversity was lower in June 2011 and August 2012 than in June 2010 and June 2014, despite these months having higher taxa richness. This indicates that even though there were more taxa present, there was a higher degree of dominance by one or a few taxa, compared to June 2010 and June 2014 when abundance was more equally distributed among taxa.

In contrast, the months February 2011, January 2012, February 2012 and March 2014 all had the lowest taxa richness (S = 6) and an uneven distribution of abundance between taxa (H'); an average of six taxa was reported for each of these months. The overall lowest diversity, however, was recorded in March 2012 (0.5166); the low H' value was a result of the low number of taxa present and the abundances dominated by only a few Arthropoda taxa (*T. longicornis*, *C. hamatus* and *Thoracica nauplius*).

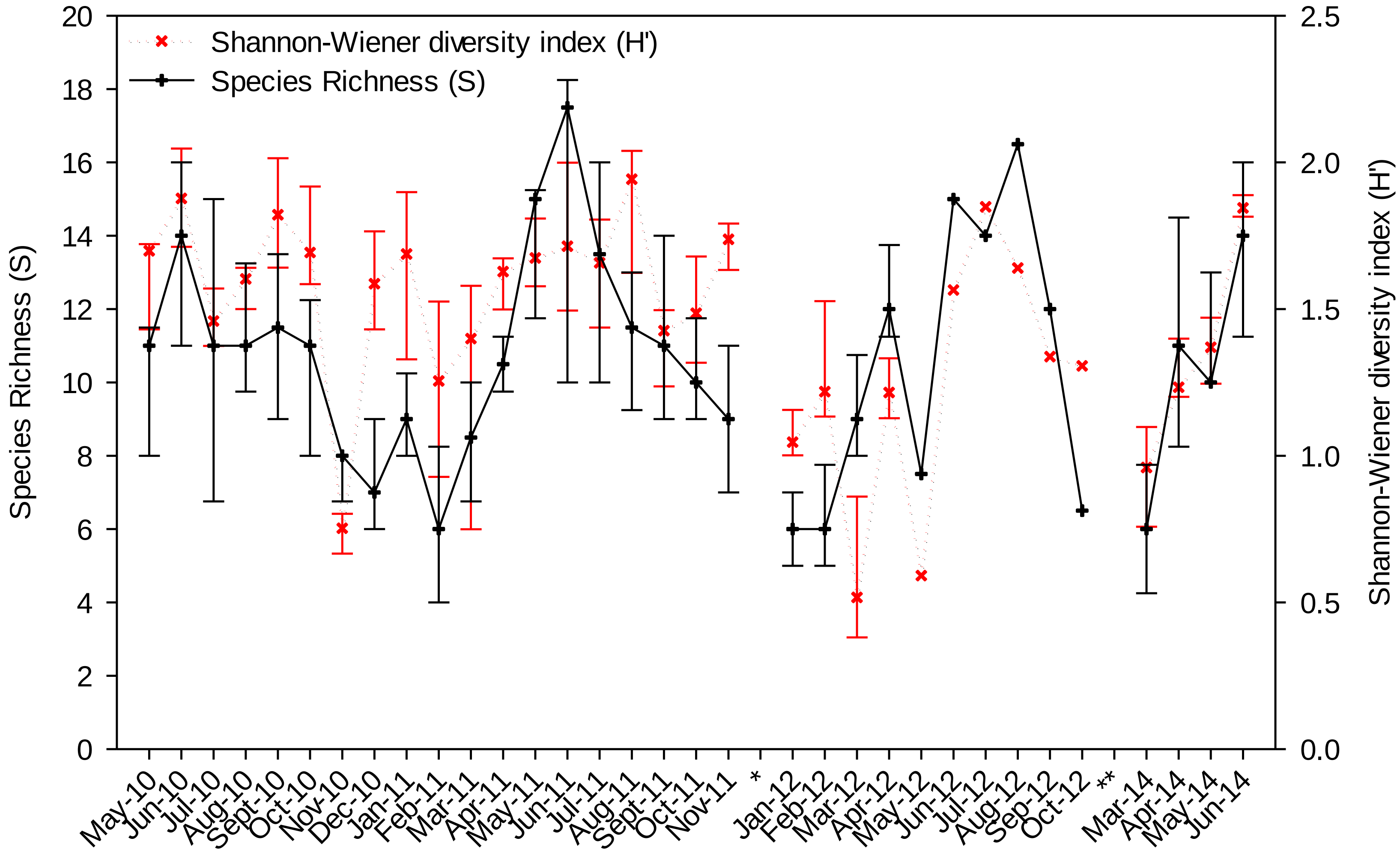


Figure 9.5 : Taxa richness and Shannon-Wiener diversity index for Arthropoda displayed by monthly median values with error bars displaying 25th and 75th percentiles. Data for samples taken between May 2010 and June 2014. Error bars not displayed between May 2012 and October 2012 as only Site 6 was sampled (two samples taken). Zooplankton samples were not taken in December 2011 (*) or during 2013 (**).

9.3.3 Copepoda

The following section describes the abundance and species composition of Copepoda off north Anglesey, and investigates the seasonal distribution of this group. Appendix L, Table L.1 shows the breakdown of Copepoda in terms of family and genus/species. Out of the five orders present off north Anglesey, a total of 21 families have been reported and within these, 29 genera have been identified with 27 copepods identified to species level.

Due to similarities in the juvenile stages of the calanoid copepods, *Paracalanus parvus* and *Pseudocalanus elongatus* can be impossible to distinguish and as such these were recorded as *Para/Pseudo –calanus*. In addition, a number of the Harpacticoid copepods that could not be identified to genus level represented the families Harpacticidae and Peltidiidae. Harpacticoid copepods occurred frequently in low numbers with seven families reported and *Longipedia*, *Alteutha* and *Euterpina* the most commonly occurring genera. Many of the individuals representing Cyclopoida could not be identified to genera with only *Oithona* confidently identified to species level. The order Poecilostomatoida was represented by two genera (*Oncaea* spp. and *Corycaeus* spp.) whereas Monstrilloida had at least two species within the same genus *(Monstrilla*).

Table 9.4 shows a marked increase in the average abundance of Calanoida in 2012, to four times the abundance recorded in other years. In all years, Calanoida was the most frequently occurring order with average abundance over monitoring years ranging between 210 and 871 individuals m^{-3}. Of the remaining orders represented here, only Harpacticoida were recorded regularly in the samples. Cyclopoida and Poecilostomatoida occurred periodically throughout the sampling period with rare encounters of Monstrilloida. Individual copepod eggs and egg sacs were present in low numbers across all years.

Table 9.4 : Average abundance (m^{-3}) for the orders of Copepoda in each year.

Order	2010	2011	2012	2014
Calanoida	282	185	871	210
Harpacticoida	6	3	21	3
Cyclopoida	1	2	2	0.191
Poecilostomatoida	1	3	0.120	0.095
Monstrilloida	0.031	0.134	0.090	0

Using the Copepoda taxa list (Appendix L, Table L.1), the most frequently occurring genera were identified as those which had contributed at least 5% to the total copepod abundance in one or more monitoring months between May 2010 and June 2014; (Figure 9.6). These genera were calanoid copepods: *Acartia*, *Paracalanus*, *Pseudocalanus*, *Temora*, and *Para/Pseudo calanus* as well as two harpacticoid copepods: *Corycaeus* and *Longipedia*.

The genus *Temora* was the most abundant taxon in the majority of sampling occasions (Figure 9.6) and was represented solely by the species *T. longicornis*. Over the whole survey period this taxon represented over 33% of the total copepod abundance, with a peak abundance seen in May 2012 (3,845 individuals m^{-3}).

Other species of calanoid copepods, such as *C. hamatus*, (represented as the genus *Centropages*) were prevalent throughout the whole period (with highest abundance of 778 individuals m^{-3} recorded in April 2012) whereas species such as *P. parvus* and *Ps. elongatus* (represented by the genera *Paracalanus* and *Pseudocalanus* respectively) appeared to have a more seasonal distribution. *Acartia* was the dominant genus during June 2010 (89 individuals m^{-3}) and second dominant in July and August 2010 (85 and 173 individuals m^{-3} respectively); subsequent sampling months saw a decline of this genus (April 2012 saw only eight individuals m^{-3}). Other genera such as *Corycaeus* and *Longipedia* were recorded in low numbers during certain months of the year.

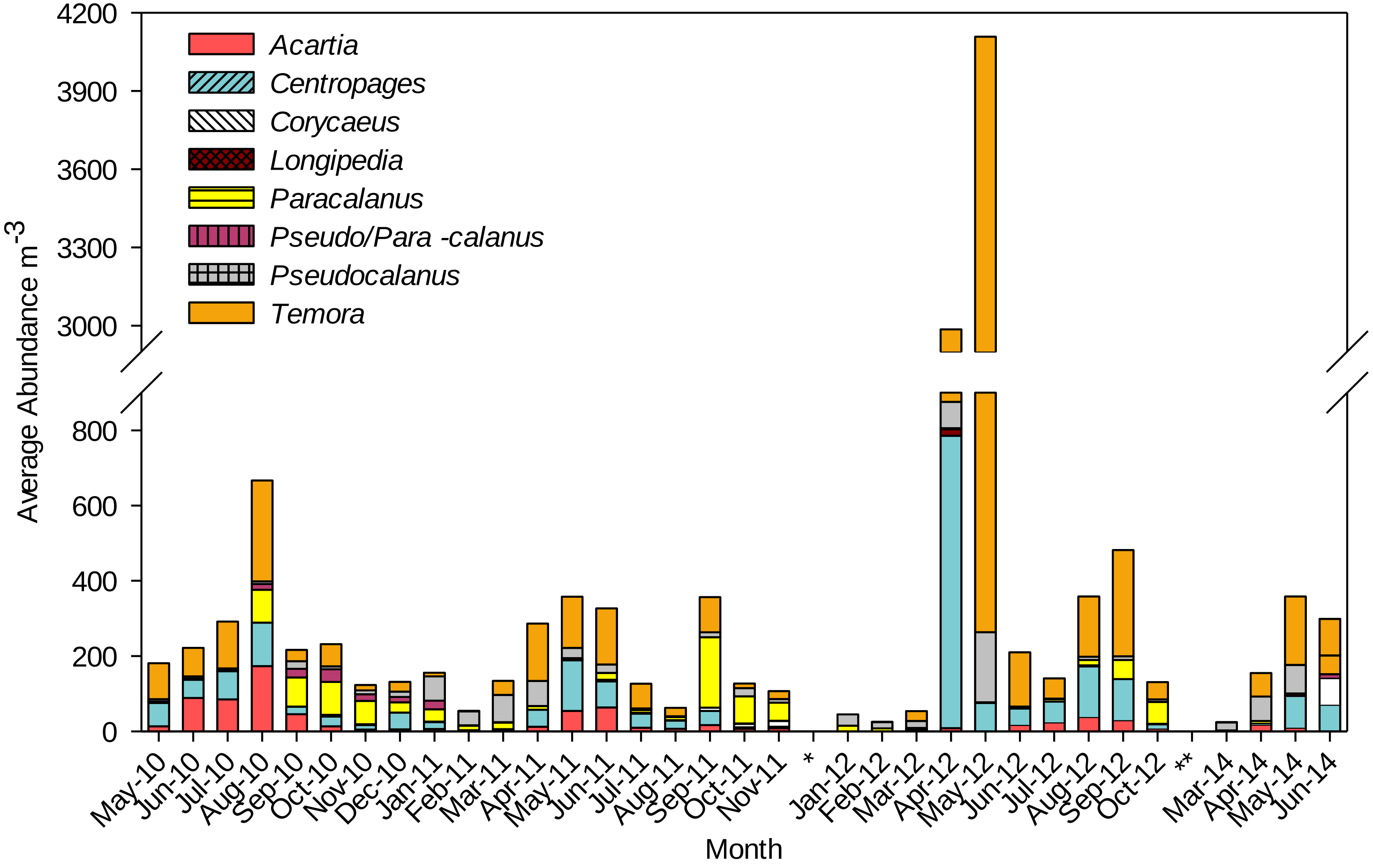


Figure 9.6 : Monthly abundances for Copepoda genera representing ≥ 5% of total copepod abundance in at least one sampling month. Zooplankton samples were not taken in December 2011 (*) or in 2013 (**). *Pseudo/Para-calanus* represents juvenile stages of the genera *Pseudocalanus* and *Paracalanus*, when these could not be speciated.

A one-way ANOSIM test using month as a factor indicated a reasonable degree of separation between the communities recorded during each sampling occasion, although some similarity was still evident (Global R = 0.448, p <0.001). Pairwise comparisons (Appendix L, Table L.6) showed that the greatest differences were generally found between months of different seasons. The results of the ANOSIM were reinforced by the pictorial representation given by a 2D–MDS plot (Figure 9.7).

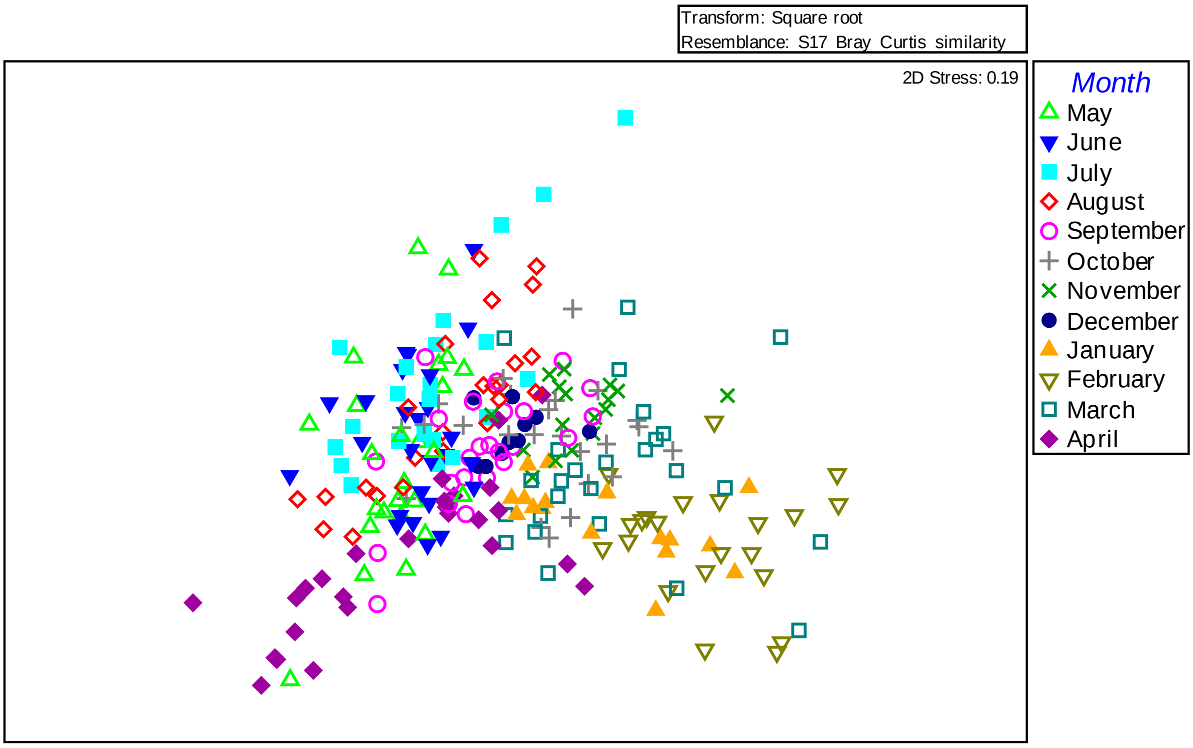


Figure 9.7 : 2D-MDS plot of Copepoda composition and abundance data off north Anglesey between May 2010 and June 2014, using month as a factor to visualise sample groupings. Stress was lower for the 3D-MDS plot (0.13), but a 2D plot is shown to facilitate better pictorial representation of sample groupings.

A two-way crossed ANOSIM, using years and seasons as factors, indicated a reasonable degree of variation between seasons (Global R = 0.484, p <0.001) particularly spring/autumn, summer/winter and autumn/winter seasons (Table 9.5).

Table 9.5 : Pairwise comparisons between seasons across all monitoring years.

Groups	R	Significance Level (%)
Spring, Summer	0.185	0.1
Spring, Autumn	0.639	0.1
Spring, Winter	0.393	0.1
Summer, Autumn	0.550	0.1
Summer, Winter	0.548	0.1
Autumn, Winter	0.639	0.1

SIMPER analysis showed that the seasonal differences were mainly due to changes in the abundance of key taxa such as *T. longicornis* and *P. parvus* (Appendix L, Table L.7). Average seasonal abundance of these common calanoid genera (see Figure 9.6) recorded the highest numbers during spring, with a clear dominance by *T. longicornis* (499 individuals m^{-3}) (Figure 9.8). As seen with *Temora* the genera *Centropages*, showed greater abundances in spring and summer by comparison with the other seasons. By contrast *Paracalanus* was most abundant in autumn and *Pseudocalanus* in winter and spring.

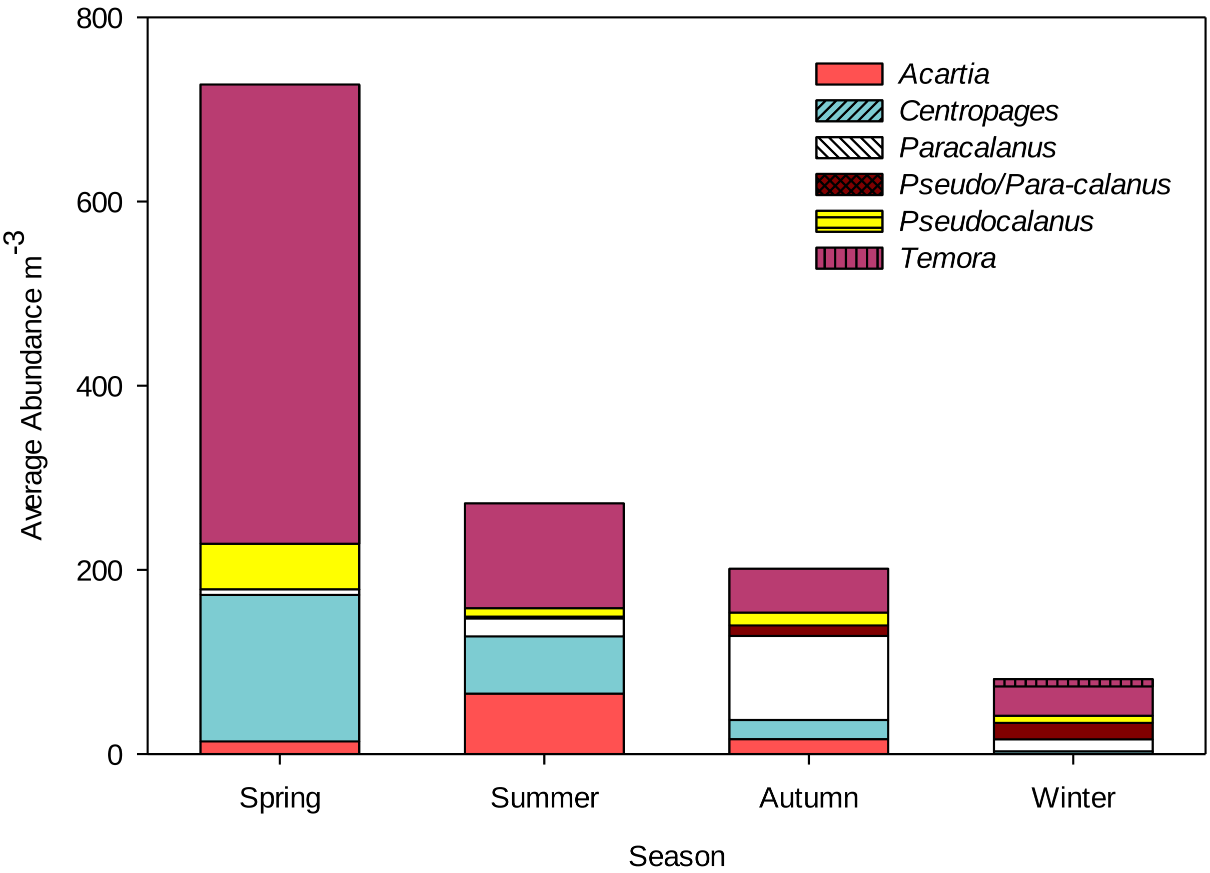


Figure 9.8 : Genera of Copepoda representing ≥5% of the total copepod abundance in at least one sampling season.

9.4 Discussion

Zooplankton contains a very wide range of organisms and representatives from many animal phyla can be found here since many species (referred to as meroplankton) have planktonic life stages before settlement. Other groups from the phylum Cnidaria and the subclass Copepoda are termed holoplankton, spending all their life in the water column.

Although the Irish Sea is relatively small when compared to other sea bodies such as the North Sea, there are large regional differences in terms of bathymetry, hydrology, nutrient chemistry and ecology (Kennington and Rowlands, 2004). The area under consideration here, similar in terms of hydrographic conditions to the eastern region studied by Graziano (1988), is situated off the coast of Anglesey and tends to be shallower than the western region; here, the waters are considered to be mixed (Pingree and Griffiths (1978), cited by Graziano (1988)).

ANOSIM testing indicated no differences between samples collected at different tidal states from different survey sites, during each survey month. However, a reasonable degree of community distinctness was found between sampling months, this being even more noticeable between seasons; the onset of varying environmental influences, such as increases in light and nutrient levels, enabling proliferation of phytoplankton and hence food availability for zooplanktonic organisms.

SIMPER analysis of the samples showed that the variations observed between years and seasons were generally a consequence of several highly abundant members of the community and their temporal variations, rather than broad changes in the community composition.

The major dominance of Arthropoda and particularly the class Copepoda, were a result of high abundances of several genera, most notably *Temora*, *Pseudocalanus*, *Paracalanus*, *Acartia* and *Centropages*; and it was mainly members from these groups that contributed the most to the observed temporal dissimilarities. However, the heterotrophic dinoflagellate *Noctiluca* sp. was the main contributor to differences between summer and other seasons; as was its frequent occurrence at high abundances in 2010 to differences between this year and others (despite the fact that this species was recorded at highest abundance in two samples in June 2012).

As detailed by Graziano (1988), the Irish Sea zooplankton composition between the east and west are similar, though a greater abundance of copepods is present in the western Irish Sea compared to the east. When looking in detail at the data collated by Graziano (1988), it is clear that the copepod taxa present in both regions were found in far greater abundance (sometimes by several orders of magnitude) in the region south-east of the Isle of Man than those found off north Anglesey. It is likely that these differences are in part due to the different sampling techniques used by Graziano (1988) where two nets with differing mesh apertures (140 µm and 350 µm) and a 0.45 m diameter were used for sampling.

Arthropoda was by far the most dominant phylum reported off Anglesey. Its taxa richness was greatest in early summer (June) 2010, 2011 and 2014 and in late summer (August) in 2012, with between 14 and 18 taxa reported on average during these months. The majority of these belonged to the class Copepoda, with fauna from this group constituting on average 63% of the zooplankton each sampling month.

A comparison between the communities recorded during this study (excluding the dinoflagellate Myzozoa) and a study carried out by Kennington and Rowlands (2004) found that a greater range of zooplankton groups were found off north Anglesey with individuals representing Chordata, Chelicerata and Brachiopoda groups occurring here. Percentage abundance of Copepoda and Annelida is 10% and 2% higher respectively, than that found in the western Irish Sea (Table 9.6). Overall though, a greater proportion of Mollusca, Bryozoa, Echinodermata and other Crustacea were reported in the western Irish Sea.

Other important zooplankton groups recorded in this north Anglesey study were members of the Crustacea (including Decapoda) and Chordata; these formed 11% and 3.8% of the zooplankton composition respectively (Table 9.6). The western Irish Sea (Isle of Man) has a larger proportion of Crustacea than that found off north Anglesey, however the general composition found within this subphylum is similar and includes Cladocera, Decapoda, Cirripedia and Euphausiidae.

Table 9.6 : Community composition for western Irish Sea (data adapted from Kennington and Rowlands, 2004) and from May 2010 to June 2014 off north Anglesey.

Group	Western Irish Sea (Isle of Man) % Composition	North Anglesey (excluding Myzozoa) % Composition
Copepoda	69.01	75.62
Other Crustacea	20.59	11.07
Mollusca	5.39	2.96
Echinodermata		
Bryozoa		
Annelida	3.07	4.74
Cnidaria	1.94	1.47
Ctenophora		
Chaetognatha		
Chordata		3.76
Other Zooplankton		0.28
Chelicerata		0.02
Brachiopoda		0.01

Cladocera were reported off north Anglesey in low numbers during spring and/or summer seasons. However, both Kennington and Rowlands (2004) and Pitois and Fox (2006) reported a consistent low population of Cladocera (genera Evadne and Podon) with Kennington and Rowlands (2004) finding Evadne to be the most frequently occurring genus. Sampling off north Anglesey has found both Podon and Evadne in similar numbers to those found by Kennington and Rowlands (2004), however, the genus Evadne was absent in the 2014 sampling; this was likely due to the reduced sampling regime rather than the absence of this genus from this region.

Thoracica nauplius and indeterminate cyprid larvae (indet.) (order Maxillopoda) appear in high numbers in this north Anglesey study, particularly in the spring, concurring with data from Kennington and Rowlands (2004) who state that the low number of continuous plankton recorder (CPR) sites in this region of the Irish Sea has underestimated the population size of these individuals in the past.

The results off north Anglesey reported only three individuals of Euphausidae (one in each of October 2011, April 2012 and May 2014) across the monitoring period. Observations by Graziano (1988) and Kennington and Rowlands (2004) show numbers of Euphausidae to be low in the Irish Sea, with lower abundances found in the east than in the west. It is highly likely that the sampling regime adopted for this study and that carried out by Graziano (1988) is not suited to catching such organisms, which have the ability to avoid slow moving sampling nets (Matthew, 1988; Ianson *et al*., 2004).

The majority of taxa reported under Arthropoda belonged to Copepoda, with Calanoida representing 98% of the Copepoda. Work by Gowen *et al*. (1998) in the western Irish Sea reported similar findings; high numbers of copepod taxa coupled with high abundances during May, June and September 1992 - 1996, when all 11 of the dominant taxa listed in Table 9.7 were reported.

When comparing results from north Anglesey with that of other parts of the Irish Sea, it is clear that there are similarities in terms of copepod species composition and seasonality of species between this region, the western and central Irish Sea, however, there are clear differences in terms of overall species abundance.

Data detailed in Table 9.7 illustrate the copepod species percentage composition for the western stratified region of the Irish Sea (Gowen *et al*., 1998), the stratified region off the coast of the Isle of Man (Kennington and Rowlands, 2004) and from this study (north Anglesey). Off north Anglesey, *T. longicornis* was the most frequently occurring copepod species, representing 55% of the copepod species composition compared to 24% off the Isle of Man, and 9% in the stratified region of the Western Irish Sea. North Anglesey species composition reported *C. hamatus* (representing 20% of the copepod composition) to be the second dominant species with *Ps. elongatus* being third dominant. In other parts of the Irish Sea, *Ps. elongatus* was dominant with *Acartia* spp. also appearing as one of the top three species.

Table 9.7 : Percentage contribution of dominant copepods to copepod abundance in the stratified region of the western Irish Sea (data calculated from Gowen *et al*., 1998) and the stratified region off the Isle of Man (data calculated from Nash (unpublished) cited in Kennington and Rowlands, 2004), compared to north Anglesey.

Species	Isle of Man % Composition	Western Irish Sea (1992-1996) % Composition	North Anglesey (2010-2014) % Composition
Acartia spp.	13.26	32.44	6.80
C. finmarchicus, *C. helgolandicus* and *Calanus* spp. copepodites	8.13	6.23	0.12
Centropages hamatus	3.29	1.56	9.63
Paracalanus parvus	2.22	2.95	6.32
Pseudocalanus elongatus	38.08	32.49	7.86
Para/Pseudo-calanus #Juv.			1.04
Temora longicornis	23.67	9.03	54.87
Oithona similis	1.37	13.98	0.14

Species	Isle of Man % Composition	Western Irish Sea (1992-1996) % Composition	North Anglesey (2010-2014) % Composition
Metridia lucens		0.71	0.001
Microcalanus pusillus		0.63	0.002
Other copepods			3.22

Studies carried out by Gowen *et al.* (1998) and Fransz *et al*. (1992) (cited in Castellani and Lucas, 2003) report *Temora* as frequently found in the coastal waters of the northern hemisphere, including the Irish Sea; our results concur with these reports with numbers of *T. longicornis* peaking in spring.

Despite declining elsewhere around the UK since August 2010, two peaks of the genus *Acartia* were observed (Gowen *et al*., 1998) in the stratified region of the western Irish Sea (Table 9.7). This is a highly productive coastal area between the lower tidal zone and continental shelf, allowing Acartia to develop and reproduce rapidly. Studies by a number of authors have found *A. clausi* (the only *Acartia* species identified off north Anglesey) to be very sensitive to starvation ((Uye, 1981; Reeve and Walter, 1977 and Paffenhofer and Stearns, 1988) all cited in Graziano, 1988). As this region of the Irish Sea appears less productive than others it could be the reason for the absence of *Acartia* sp. observed at certain times of the year e.g. during the winter season.

The seasonal distributions of the main copepod species found off north Anglesey complements the findings by Graziano (1988) and Kennington and Rowlands (2004) with similar seasonal distributions observed for five dominant copepod genera (*Temora, Centropages, Pseudocalanus, Acartia* and *Paracalanus*) found off north Anglesey; this was particularly true for both *T. longicornis* and *Acartia* spp.. Species abundances show a greater degree of fluctuation with higher numbers of *Ps. elongatus* and *Acartia* spp. reported by Kennington and Rowlands (2004) compared to higher numbers of *T. longicornis* and *C. hamatus* reported here.

The variation in abundance of certain species, in particular the small copepod *Oithona* spp. and juvenile stages of *P. parvus* and *Ps. elongatus* can potentially be explained by the variation in sampling techniques. The surveys off north Anglesey detailed in this report (2010-2014) and those carried out by Williamson (1956) utilised a 250 µm mesh size whilst Gowen *et al*. (1998) utilised a 300 µm mesh size. Since Graziano (1988) sampled with two nets of differing mesh sizes (140 and 350 µm), the smaller aperture net (140 µm) would capture both the juvenile stages and the smaller species of copepods and this could explain the very low abundance of *Oithona* spp. found off north Anglesey compared to this taxa ranking as fifth most dominant by Graziano (1998).

Figueiredo *et al*. (2009) also suggested that the actual population of the smaller copepods for the Irish Sea has in the past been underestimated and that these species actually dominate the copepod population; stating that the adult contribution to the copepod biomass of species including *Calanus* spp., *C. hamatus*, *Ps. elongatus* and *T. longicornis* is much lower than that of the small copepods. Other reasons for changes in abundances may be linked to the natural variation and changes in climatic conditions across the years.

Other taxa found in low abundances during the surveys were *Calanus* spp., with *C. helgolandicus* the most commonly recorded. Overall, *Calanus* spp. represented less than 1% of the Copepoda composition in this study and since they generally occur in higher abundance in the stratified region of the Western Irish Sea (Graziano, 1988 and Gowen *et al*., 1998) this result is not unusual and Graziano (1988) believes this could be related to differences in the phytoplankton cycle observed in these different regions.

The nutritional composition of phytoplankton in stratified waters compared to mixed waters is thought to be very important in terms of the community composition of the zooplankton. Oviatt (1981) cited in Graziano (1988) showed zooplankton biomass to be far greater in stratified waters and this has been linked to the differential fecundity and growth rates arising from phytoplankton composition in terms of flagellates and diatoms. It is known that diatoms have a lower calorific value when compared to dinoflagellates, with less carbohydrates, proteins and lipids by volume base (Hitchcock, 1985, cited in Graziano, 1988). Well-mixed areas of the Irish Sea generally have a greater abundance of diatoms and this is certainly true off north Anglesey (Section 8.3). In these areas, copepods such as *Calanus* (found in very low numbers during the monitoring period (2010 - 2014)) lack the nutritious diet that summer domination of dinoflagellates gives. Species such as those belonging to the genus *Acartia* are found in high abundances in the North Channel (Kennington and Rowlands, 2004); whilst Gowen *et al*. (1998) found that in the North Channel increased copepod abundance actually preceded the summer peak in primary production which was not the case in other parts of the Irish Sea. Since primary production off north Anglesey was found to be lower than areas of the western Irish Sea this would also be true if one compares it to the North Channel (see Section 8.4).

Although primary production is lower in north Anglesey, patterns can still be determined when considering both phytoplankton and zooplankton. Here, the abundance of Copepoda was associated with the abundance of microflagellates and diatoms rather than the abundance of dinoflagellates (Figure 9.9). It is clear from Figure 9.9 that the highest abundance of Copepoda found in May 2012 was around the same time as the peak diatom abundance and a month after the microflagellate bloom that occurred in April 2012 (see Section 8.3.1).

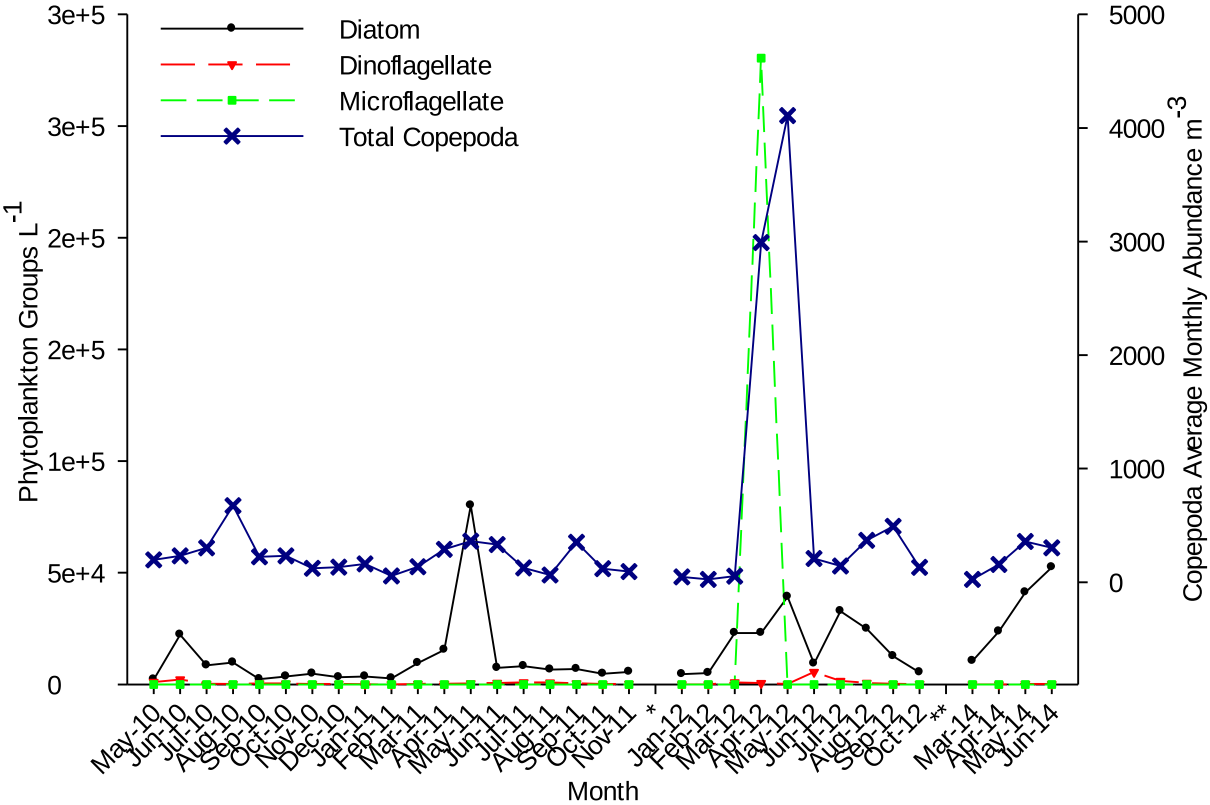


Figure 9.9 : Average abundance of Copepoda compared to the various phytoplankton groups (diatoms, dinoflagellates and microflagellates) between May 2010 and June 2014.

Copepods are known to be an important food source for many commercial fish species, their presence being essential to the survival of developing larvae (Kennington and Rowland, 2004). Investigations into the diet of gadoid species (e.g. whiting (*Merlangius merlangus*), cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) have found changes in food sources with increasing body size. Young gadoid larvae feed on copepod nauplii, progressing from small copepods such as *Acartia* spp. to *T. longicornis* and *P. parvus* and then onto the large *Calanus* spp. (Rowlands *et al*., 2006; Kennington and Rowlands, 2004). Rowlands *et al*. (2006) concluded that in the Irish Sea, two gadoid species (whiting and cod) between stage 2 larvae and juveniles were dependent on copepods for their diet and in particular *Calanus* abundance for the juvenile stage. Furthermore, Thompson and Harrop (1991) studied the diet of cod larvae in the Irish Sea and found larvae >5 mm fed on copepod nauplii; larval lengths between 5 and 9 mm fed on copepodites and larvae measuring between 10 and 20 mm fed mainly on adult copepods.

There have been no protected species of zooplankton identified from the waters off north Anglesey; however, a number of benthic species of conservation importance, which have planktonic larval life stages have been identified from other baseline surveys of the monitoring programme (e.g. dive, intertidal biotope and subtidal grab surveys). These species are:

- *Mytilus edulis* (blue mussel); blue mussel beds on sediment are a UK BAP priority habitat;
- *Modiolus modiolus* (horse mussel, previously named *Mytilus modiolus*); horse mussel beds are an Annex I habitat;
- *Sabellaria spinulosa* and *S. alveolata*; *Sabellaria* reefs are an Annex I habitat; and,
- *Palinurus elephas* (spiny lobster); spiny lobster is a UK BAP priority species.

Since all of the above species have planktonic larval life stages, their presence within the north Anglesey coast zooplankton community is expected. *Mytilus* spp. was recorded within the zooplankton and could therefore represent both the blue mussel and the horse mussel. *Sabellaria* sp. was also recorded within the zooplankton and could represent *S. spinulosa* and/or *S. alveolata*. The spiny lobster could have been recorded under the order Decapoda.

Finally, the invasive non-native barnacle *Austrominius modestus* was recorded from benthic surveys at the power station outfall and was most likely recorded in the zooplankton within the group of barnacle larvae (thoracica nauplii). *Caprella* sp. was also identified from zooplankton samples; this could be a representative of the invasive Japanese skeleton shrimp, *Caprella mutica*, which is a non-native marine species of concern in north Wales.

10. Concluding Remarks

Water quality monitoring conducted off north Anglesey indicates a well-mixed water body with no evidence of a permanent thermocline, halocline or seasonal stratification. Nutrient concentrations were low throughout the monitoring period with no indication of eutrophication. Discharges from the power station did not have any significant effect on the quality of the coastal water body, with the exception of the water temperature within the immediate vicinity from the discharge.

Due to the low nutrient concentrations off the north Anglesey coast, phytoplankton abundance and chl-a concentrations remained relatively low compared to other areas of the Irish Sea. No phytoplankton bloom densities were reached under WFD, although a seasonal increase in abundance during the spring period was still evident. Relatively high mixing of the water body favoured an overall numerical dominance by diatoms, even during the summer months when stratification of the water column traditionally favours the dominance of dinoflagellates.

Zooplankton abundance was numerically dominated by Copepoda and exhibited a lag response to the seasonal peaks in phytoplankton abundance. The relatively low density of zooplankton, with particularly low abundances of the copepod *Calanus* spp., could be attributed to the low nutritional value of their available food source (diatoms) compared to dinoflagellates.

11. References

BEEMS (2011). Chlorination by-products in power station cooling waters. Scientific Advisory Report Series 2001 no. 009, 27pp.

Bamber, R. N., Evans N. J. and Whittall, A. M. 2000. Survey of Potential Coastal Saline lagoons and Pools in Wales, December 1998. Natural History Museum Consultancy Report No. ECM 646/99; 67pp. CCW Contract Science Report No. 377

Bamber, R. N., Evans, N. J., Sanderson, W. G. and Whittall, A. 2001. Coastal saline lagoons and pools in Wales: review and proposals. Bangor, CCW Contract Science Report No 464: 69pp.

Castellani, C. and Lucas, I.A.N. (2003). Seasonal variation in egg morphology and hatching success in the calanoid copepods *Temora longicornis*, *Acartia clausi* and *Centropages hamatus*. *Journal of Plankton Research*. **25** (5), 527-537.

Centre for Environment, Fisheries and Aquaculture Science (Cefas). (2011). Radioactivity in Food and the Environment, 2010. RIFE – 16 report. CEFAS, 248 pp.

Centre for Environment, Fisheries and Aquaculture Science (Cefas). (2012). Radioactivity in Food and the Environment, 2011. RIFE – 17 report. CEFAS, 254 pp.

Clarke, K.R. and Gorley, R.N. (2006). PRIMER v6: User Manual/Tutorial, PRIMER-E, Plymouth.

Clarke, K.R. and Warwick, R.M. (2001). Change in Marine Communities: An approach to statistical analysis and interpretation, PRIMER-E, Plymouth UK.

Centre for Marine and Coastal Studies (CMACS). (2006). Liquefied Natural Gas Plant, Amlwch, Anglesey Environmental Impact Assessment. CMACS Report to Hyder Ltd J3050 TRv1.4. 129 pp.

Cooper, L.H.N. (1937). Oxidation-reduction potential in sea water. *Journal of the Marine Biological Association of the United Kingdom,* **22** (1). pp. 167-176

Currie, L.A. (1968). Limits of qualitative detection and quantitative determination. Analytical Chemistry, 40 (3), 586-593.

Department of Energy and Climate Change. (2011). National Policy Statement for Nuclear Power Generation (EN-6). [Online] [Accessed March 2016] Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47859/2009-nps-for-nuclear-volumeI.pdf..

Department for Environment, Food and Rural Affairs (Defra). (2000). Quality status report of the Marine and coastal areas of the Irish Sea and the Bristol Channel. Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Department of the Environment, Transport and the Regions, London.

Eloire, D., Somerfield, P.J., David V. P., Conway, D.V.P., Halsband-Lenk, C., Harris, R. and Bonnet, D. (2012). Temporal variability and community composition of zooplankton at station L4 in the Western Channel: 20 years of sampling. *Journal of Plankton Research*. **32** (5), 657-679.

Elangovan, S.S., Kumar, M.A., Karthik, R., Sankar, R.S., Jayabarathi, R. and Padmavati, G. (2010). Abundance, species composition of microzooplankton from the coastal waters of Port Blair, South Andaman Island. *Aquatic Biosystems 2012* **8** (20), 9 pp.

Eno, N.C., Clark, R.A. and Sanderson, W.G. (1997). Non-native marine species in British waters: a review and directory. Peterborough: Joint Nature Conservation Committee, 136 pp.

Environment Agency (2005). EU Habitats and Bird Directive Handbook (Appendix 3): Applying the Habitats Regulations to Water Quality Permissions to discharge: Review and New Applications. Environment Agency Document No. 115_05, May 2005.

Environment Agency (2010). *Cooling water options for the new generation of nuclear power stations in the UK*. Jacobs UK Limited for the Environment Agency. Bristol.

Epworth, B. and Haycock, N. 2006. Cemlyn Lagoon: Review of the Water Level Management Plan. Report to the National Trust by Haycock Associates. Pershore, Worcestershire, 42pp.

Figueiredo, G.M., Montagnes, D.J.S. and Nash, R.D.M. (2009). The importance of protozooplankton as prey for copepods in the coastal areas of central Irish Sea. *Hydrobiologica*. **628**, 227-239.

Gilmore G. and Hemingway J. (1995). Practical gamma-ray spectrometry. John Wiley & Sons, Chichester, UK, 314pp

Goericke, R. and Repeta, D.J. (1992). The pigments of *Prochlorococcus marinus*: The presence of divinyl chlorophyll a and b in a marine prokaryote. *Limnology and Oceanography*. **37**, 425 – 433.

Gowen, R.G., Mills, D. K., Trimmer, M. and White M. (2000). Production and its fate in two coastal regions of the Irish Sea: the influence of anthropogenic nutrients. *Marine Ecology Progress Series*. **208**, 51 – 64.

Gowen, R.J. and Stewart, B.M. (2005). The Irish Sea: Nutrient status and phytoplankton. *Journal of Sea Research*. **54**, 36 – 50.

Gowen, R.J., Tett, P., Kennington, K., Mills, D.K., Shammon, T.M., Stewart, B.M., Greenwood, N., Flanagan, C., Devlin, M. and Wither, A. (2008). The Irish Sea: Is it eutrophic? *Estuarine, Coastal and Shelf Science*. **76**, 239 – 254.

Gowen, R.J., McCullough, G., Dickey-Collas, M. and Kleppel, G.S. (1998). Copepod abundance in the western Irish Sea: relationship to physical regime, phytoplankton production and standing stock. *Journal of Plankton Research* **20**(2), 315-330.

Graziano, C. (1988). Some observations of plankton in the Irish Sea. PhD Thesis. University of Liverpool. 121 pp.

Greenwood, N., Forster, R. M., Créach, V., Painting, S. J., Dennis, A., Cutchey, S. J., Silva, T., Sivyer, D. B. and Jickells, T. (2011). Seasonal and interannual variation of the phytoplankton and copepod dynamics in Liverpool Bay. *Ocean Dynamics*. **62**, 307 – 320.

Ianson, D., Jackson, G.A., Angel, M.V., Lampitt, R.S. and Burd, A.B. (2004). Effect of net avoidance on estimates of diel vertical migration. *Limnology Oceanography*, **49** (6), 2297–2303.

IOC, 2010: The international thermodynamic equation of seawater – 2010: Calculation and use of thermodynamic properties. Intergovernmental Oceanographic Commission, Manuals and Guides No. 56, UNESCO (English), 196 pp.

IUPAC (1997). Compendium of Chemical Terminology, 2nd Edition. (the "Gold Book"). Blackwell Scientific Publications, Oxford (1997). XML online corrected version: http://goldbook.iupac.org/ (2006-).

Jenner, H.A., Taylor, C.J.L., van Donk, M., Khalanski, M. (1997) Chlorination by-products in chlorinated cooling water of some European coastal power stations, *Marine Environmental Research* **43**, 279-293.

Jones D. C. 1978. The Ecology of Two Coastal lagoons. MSc Dissertation, University of Wales; 122pp

Kennington, K. and Rowlands, W.Ll. (2004) SEA area 6: Technical report – Plankton ecology of the Irish Sea. University of Liverpool. Port Erin Marine Laboratory. (Online). Available at:

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/197299/SEA6_Plankton_PEML.pdf

Kennington, K., Allen, J.R., Wither, A., Shammon, T.M. and Hartnoll, R.G. (1999). Phytoplankton and nutrient dynamics in the north-east Irish Sea. *Hydrobiologia*. **393**, 57 – 67.

Llewellyn, C.A., Fishwick, J.R. and Blackford, J.C. (2005). Phytoplankton community assemblage in the English Channel: a comparison using chlorophyll-a derived from HPLC-CHEMTAX and carbon derived from microscopy cell counts. *Journal of Plankton Research*. **27**, 103 – 119.

Lund, J.W.G., Kipling, C. and Le Cren, E.D. (1958). The inverted microscope method of estimating algal numbers and the statistical basis of estimation by counting. *Hydrobiologia*. **11**, 143 – 170.

Madrid, Y. and Pedrero Zayas, Z. (2007). Water sampling: Traditional methods and new approaches in water sampling strategy. *Trends in Analytical Chemistry*. **26**(4), 293-299.

Matthew, K.J. (1988). Net avoidance behaviour among larval, juvenile and adult euphausids. *Journal of Marine Biological Association India*. **30**(1&2), 93-98.

Met Office (2016). Weather summaries (available Online): http://www.metoffice.gov.uk/climate/uk/summaries/ [Accessed: 02 March 2016].

Nikitik, C. 2007. Benthic Invertebrate Communities in Cemlyn lagoon, Anglesey, North Wales. Environment Agency Wales SE Area Environmental Appraisal Team Ref. No. EASE/TM/07/200, 17pp

Ohrel, R.L. Jr. and Register, K.M. (2006). Volunteer Estuary Monitoring: A Methods Manual (Second Edition) (2006). U.S. Environmental Protection Agency. The Ocean Conservancy. 396 pp.

Pitois, S.G. and Fox, C.J. (2006). Long-term changes in zooplankton biomass concentration and mean size over the Northwest European shelf inferred from Continuous Plankton Recorder data. *ICES Journal of Marine Science*. **63**, 785-798.

Rowlands, W.LI, Dickey-Collas, M., Geffen, A.J. and Nash, R.D.M. (2006). Do gadoids really prefer *Calanus*? The prey selection through metamorphosis in Irish Sea cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and whiting (*Merlangius merlangus*). Report by ICES CM 2006/F:14. 20 pp.

SNIFFER (2008). UKTAG Coastal Water Assessment Methods. Phytoplankton multi-metric tool kit. WFD UK TAG, 22 pp.

Thompson, A.B. and Harrop, R.T. (1991). Feeding dynamics of fish larvae on Copepoda in the western Irish Sea, with particular reference to cod (*Gadus morhua*). *Marine Ecological Progress Series*. **68**, 213-223.

Titan environmental Survey (2012). Wylfa Oceanography Interpretive Report. Report number WYL-TES-PAC-REP-00024

Turekian, K.K. (1976). Oceans (Foundations of Earth Science) 2nd Edition. 1976, Prentice-Hall, 149pp.

Williamson, D.I. (1956). Planktonic evidence for irregular flow through the Irish Sea and north channel in the autumn of 1954. *Journal of the Marine Biological Association UK*. **35**, 461-466.

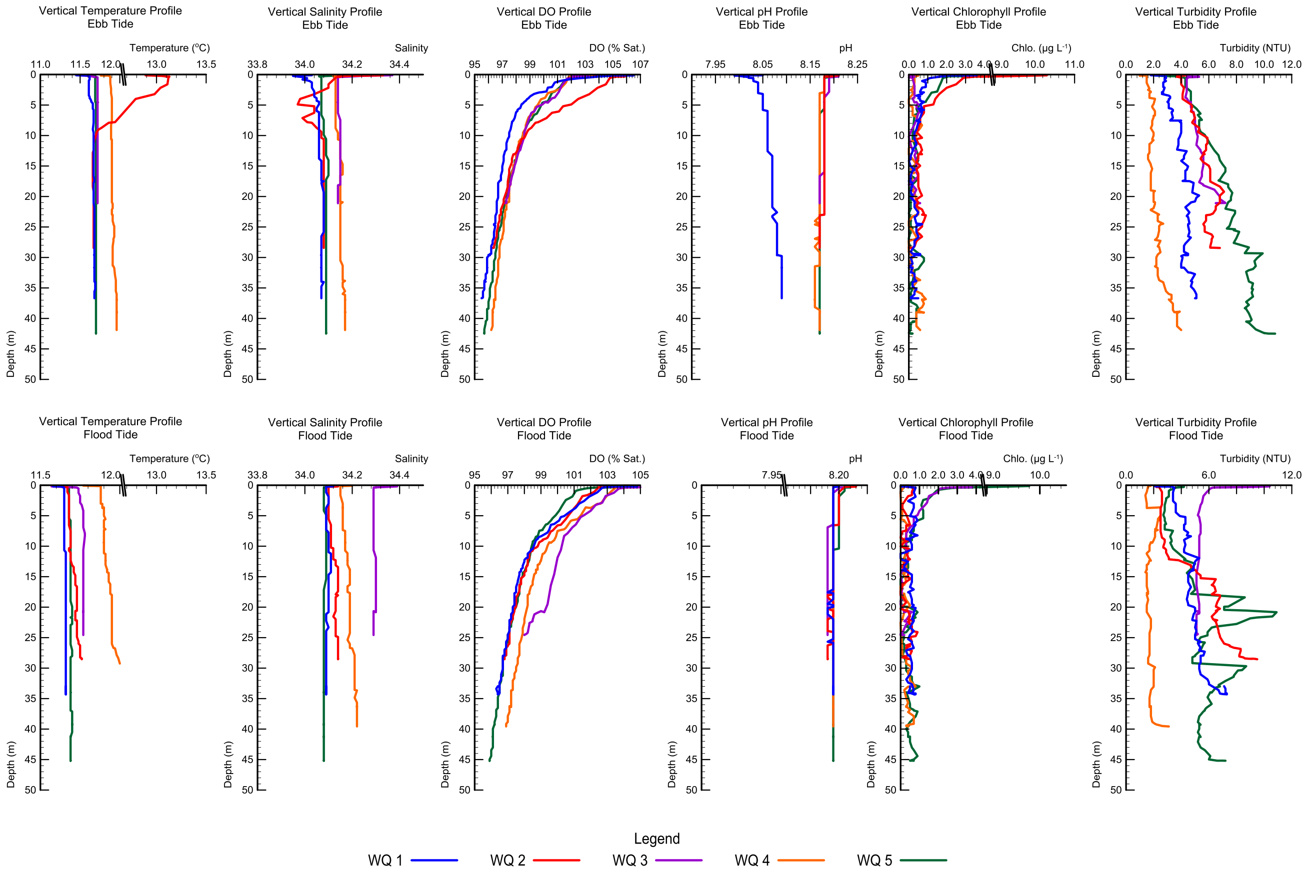
WoRMS Editorial Board (2015). World Register of Marine Species. Available from http://www.marinespecies.org Accessed 2015-02-10

YSI (2006). 6-Series Multiparameter Water Quality Sondes User Manual. Section 5-21.

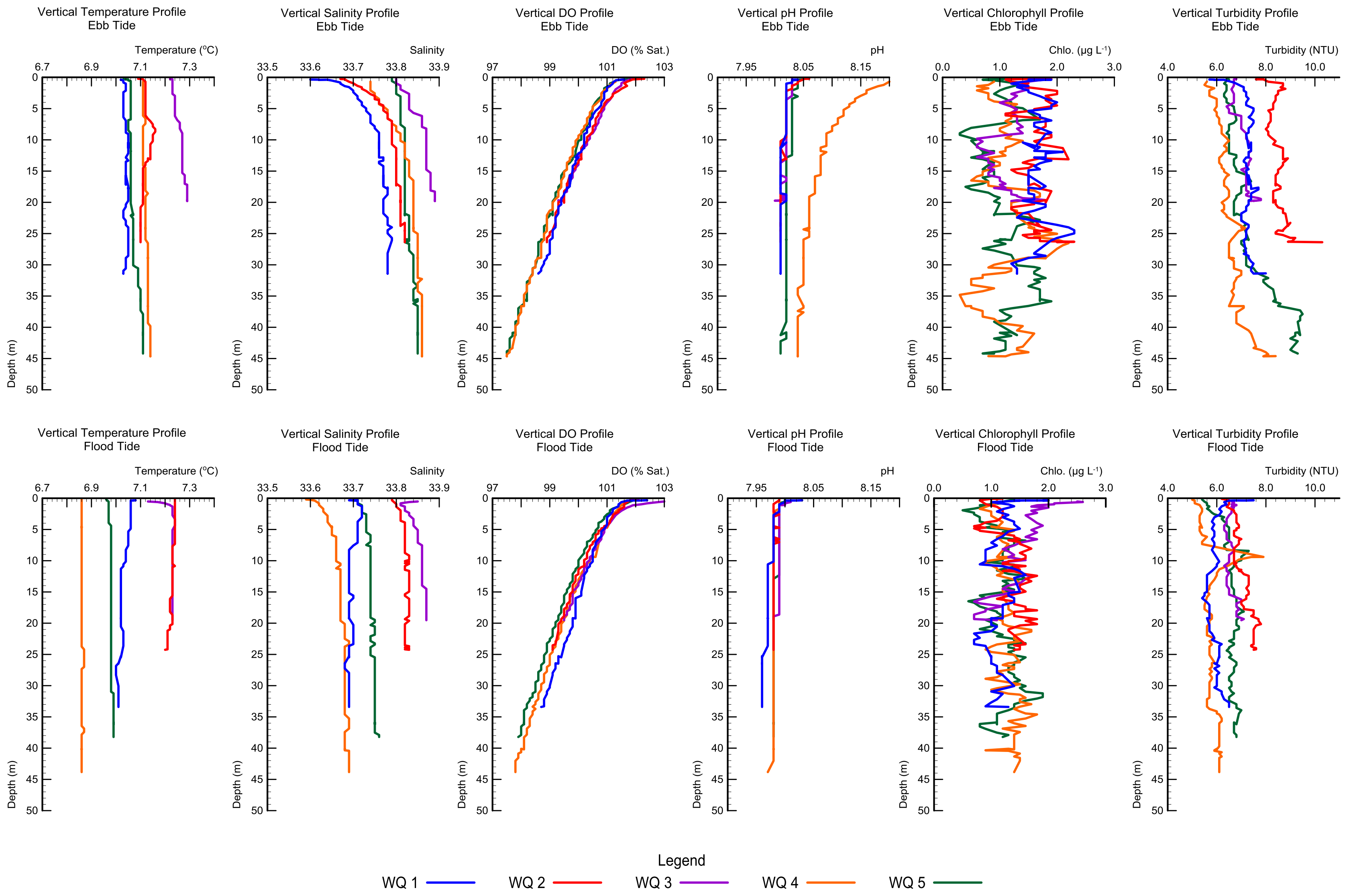
Appendix A. Water Quality – Vertical Profiles

This Appendix only presents a selection of water column vertical profiles recorded between May 2010 and November 2014.

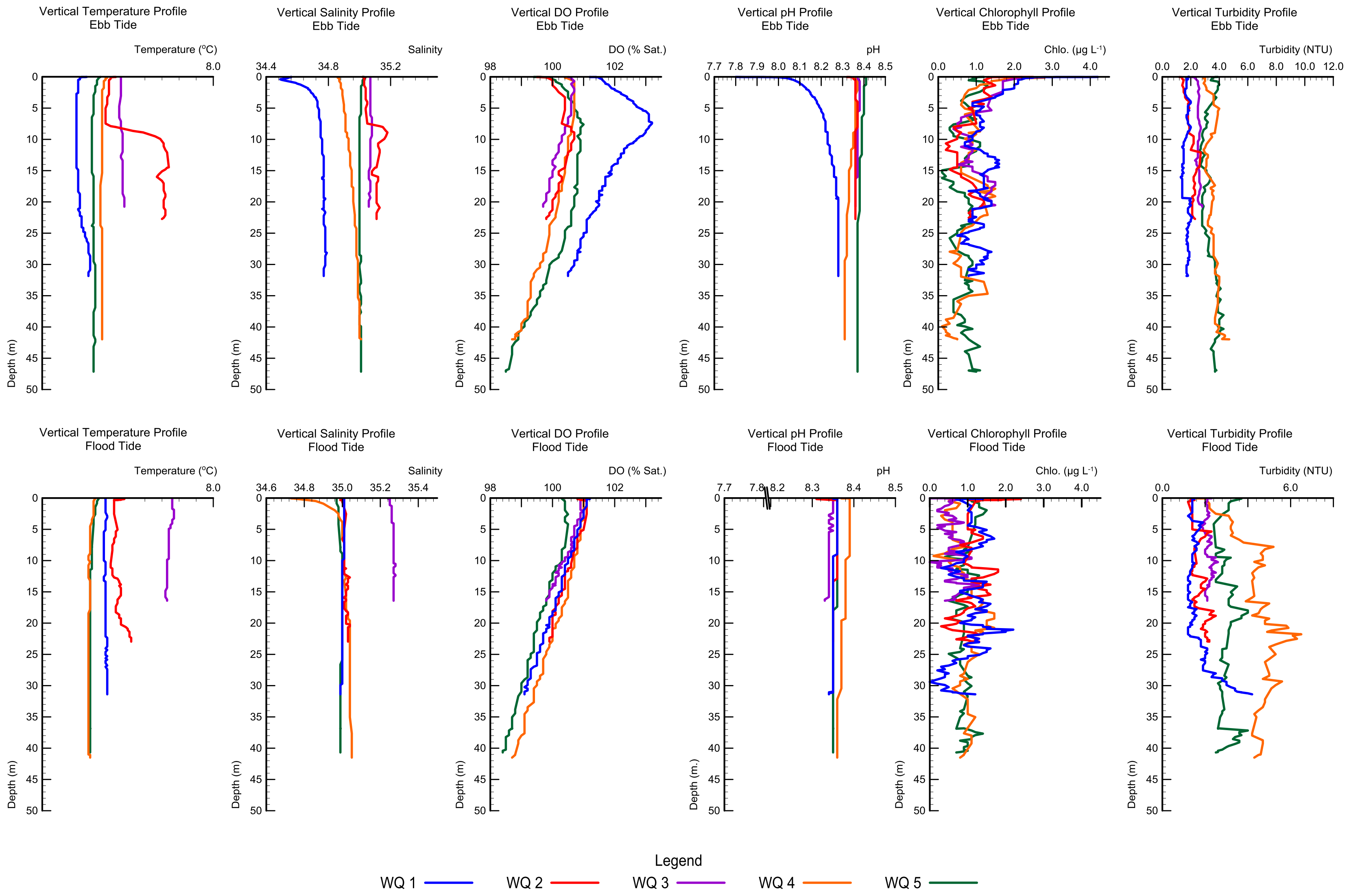
Vertical Water Column Profiles for November 2010



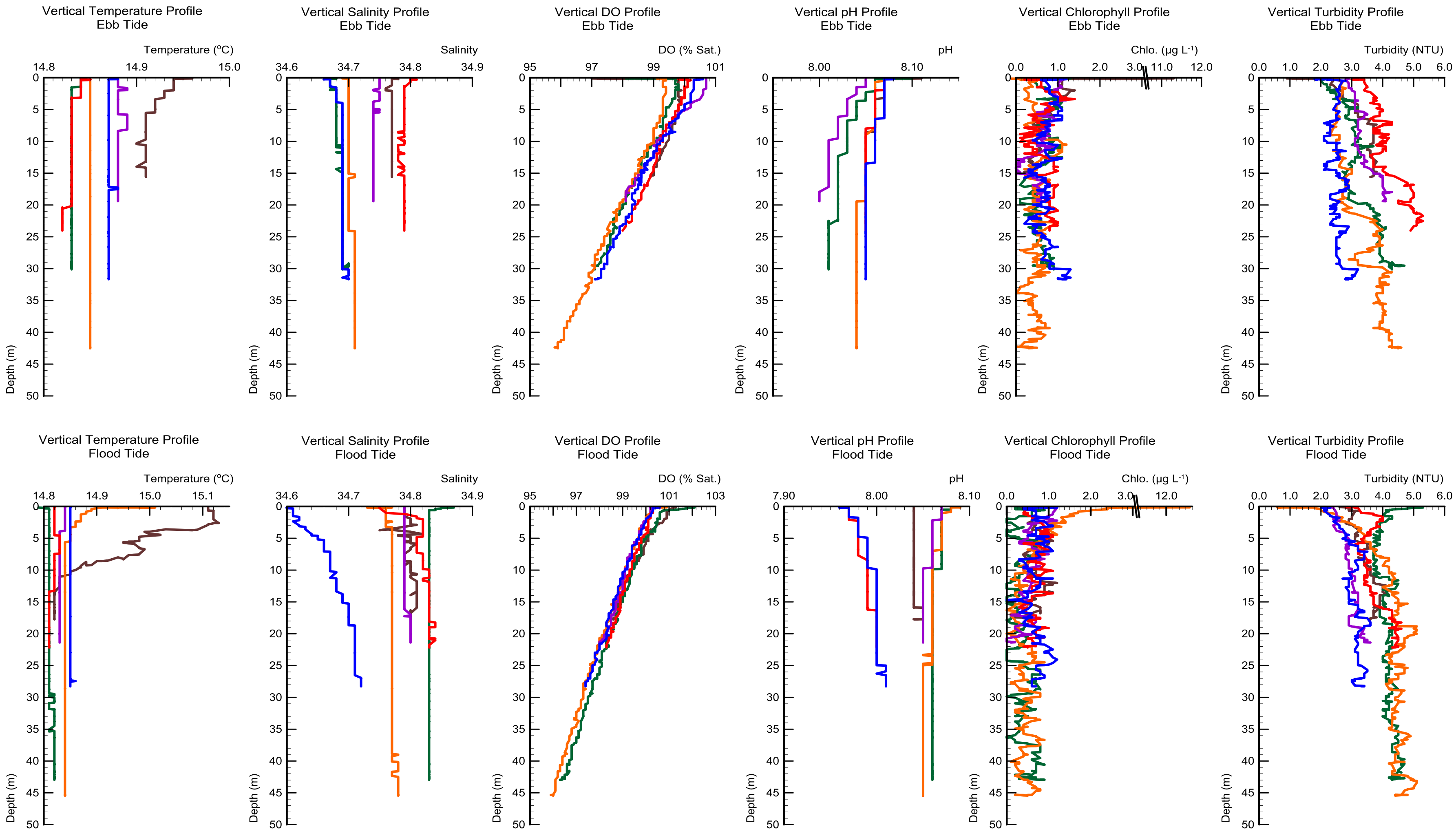
Vertical Water Column Profiles for January 2011



Vertical Water Column Profiles for March 2011



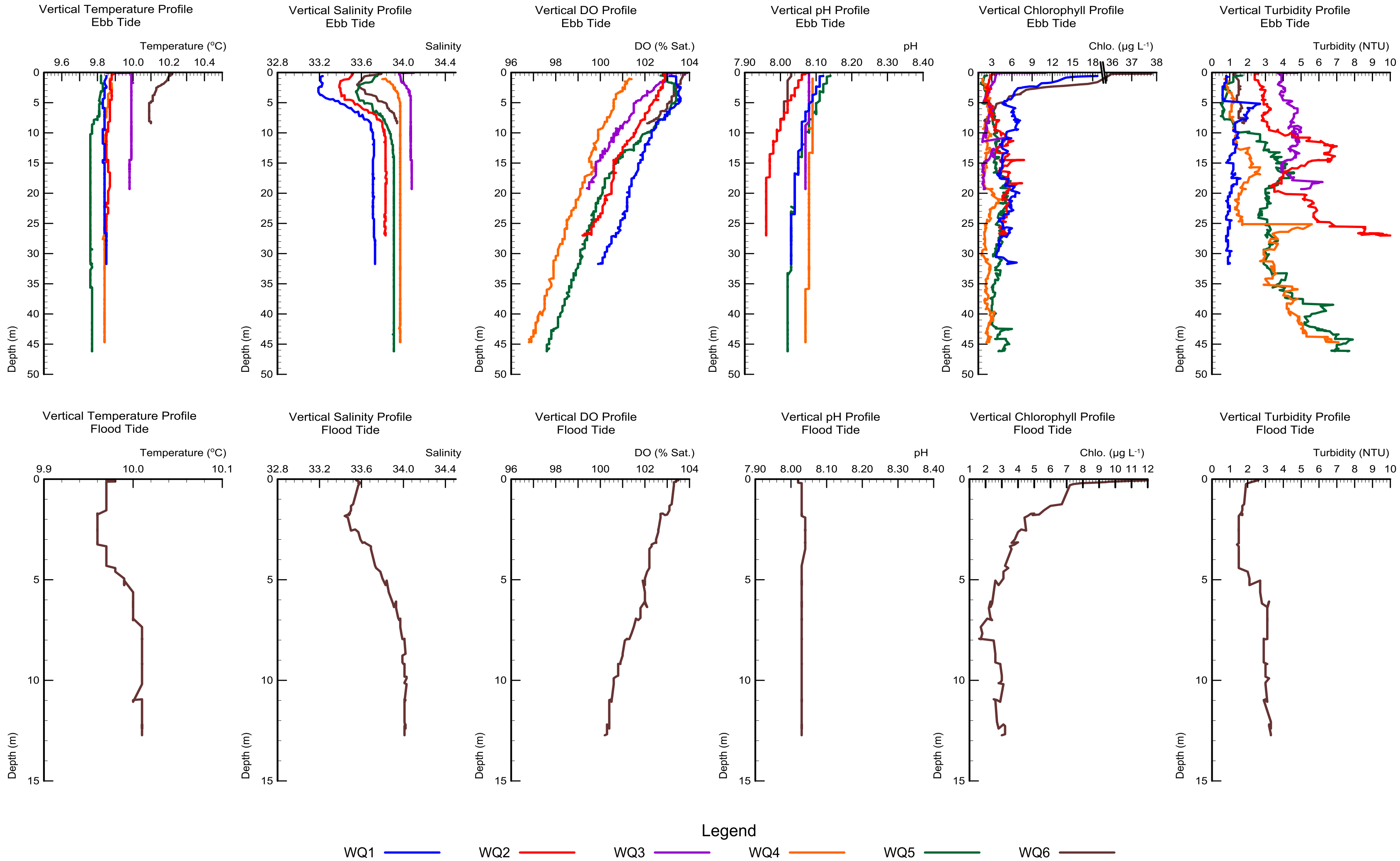
Vertical Water Column Profiles for October 2011



Legend

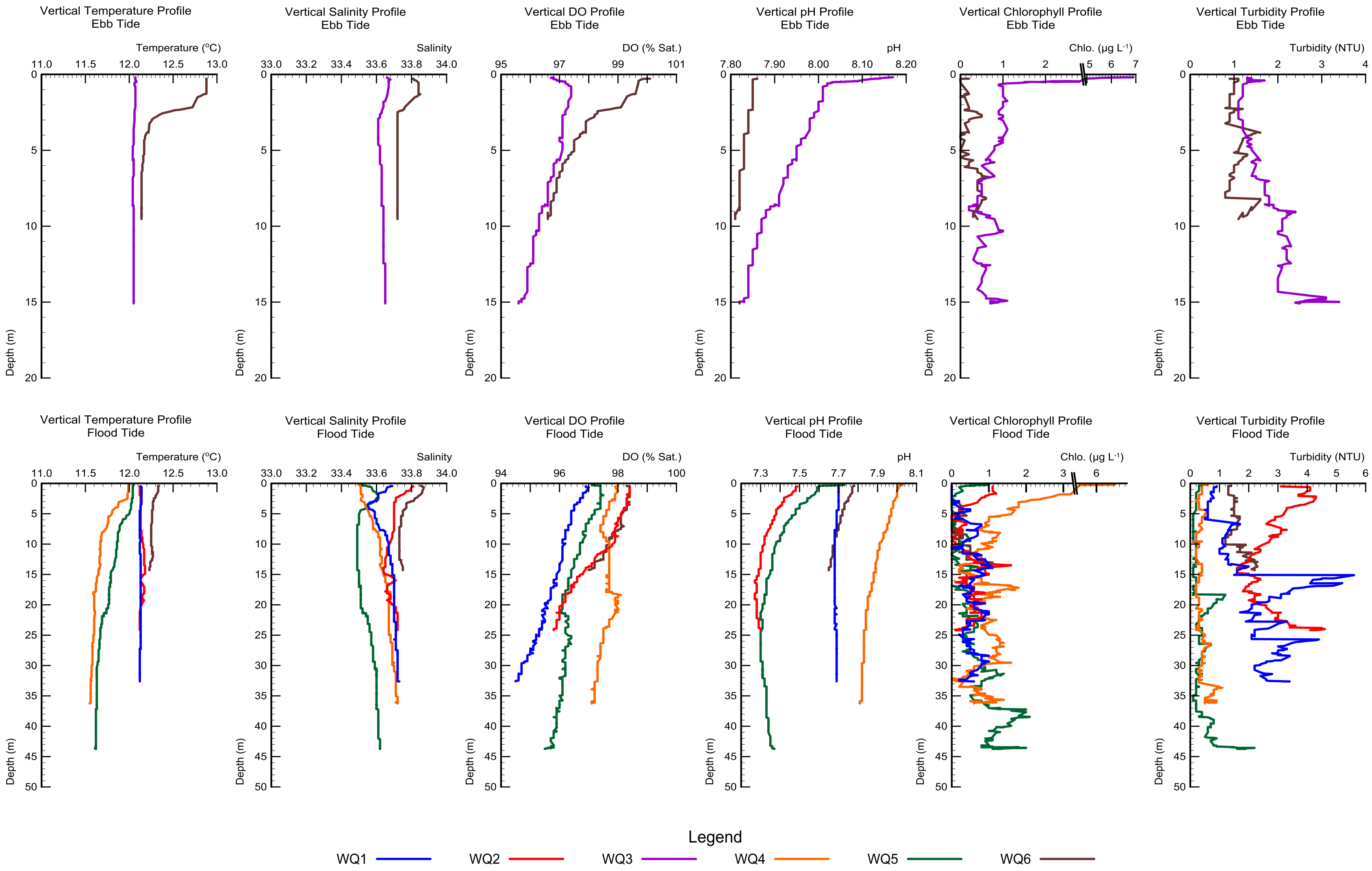
Vertical Water Column Profiles for May 2012

(Random tide survey - except at site WQ 6)

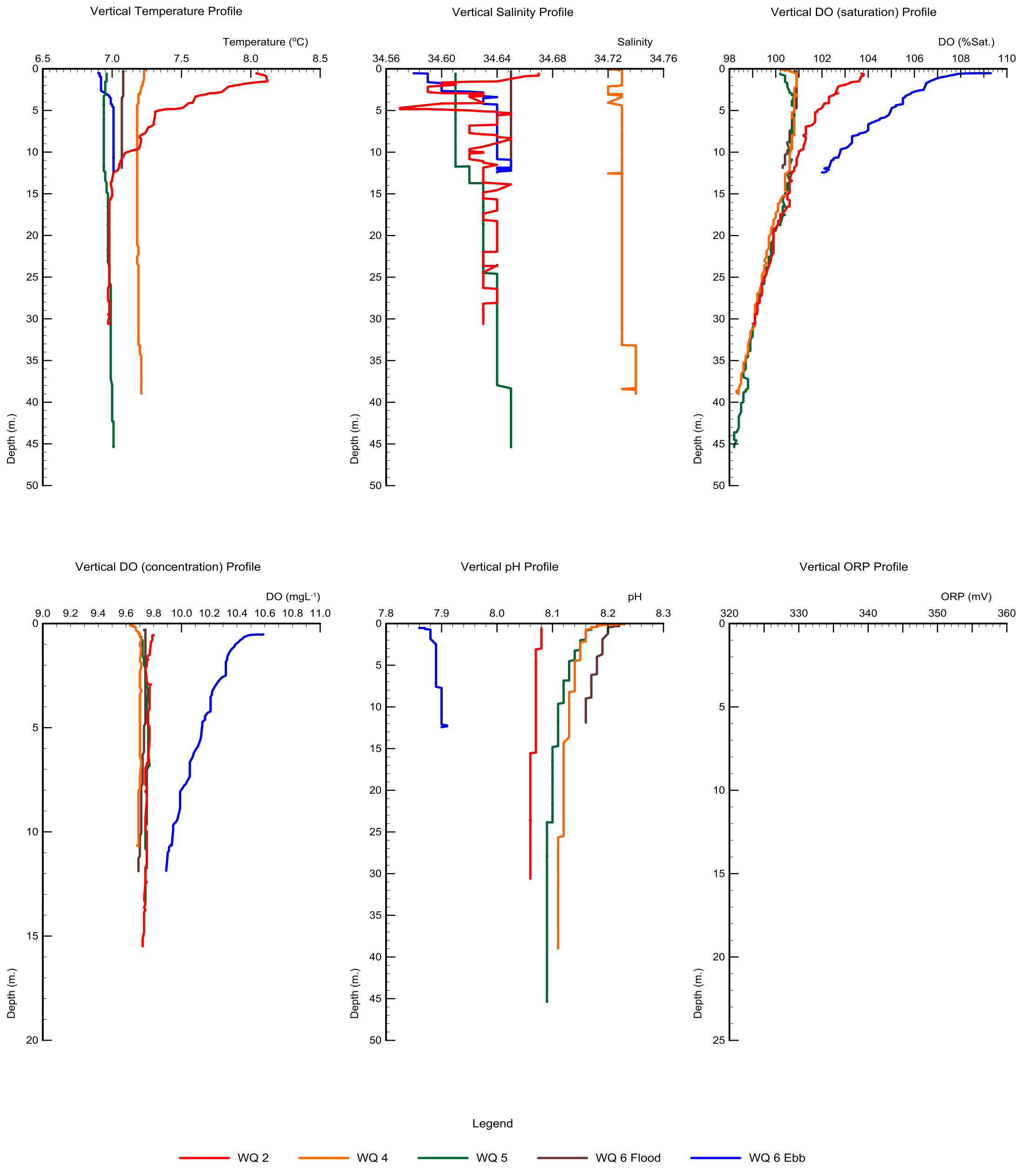


Vertical Water Column Profiles for June 2012

(Random tide survey - except at site WQ 6)

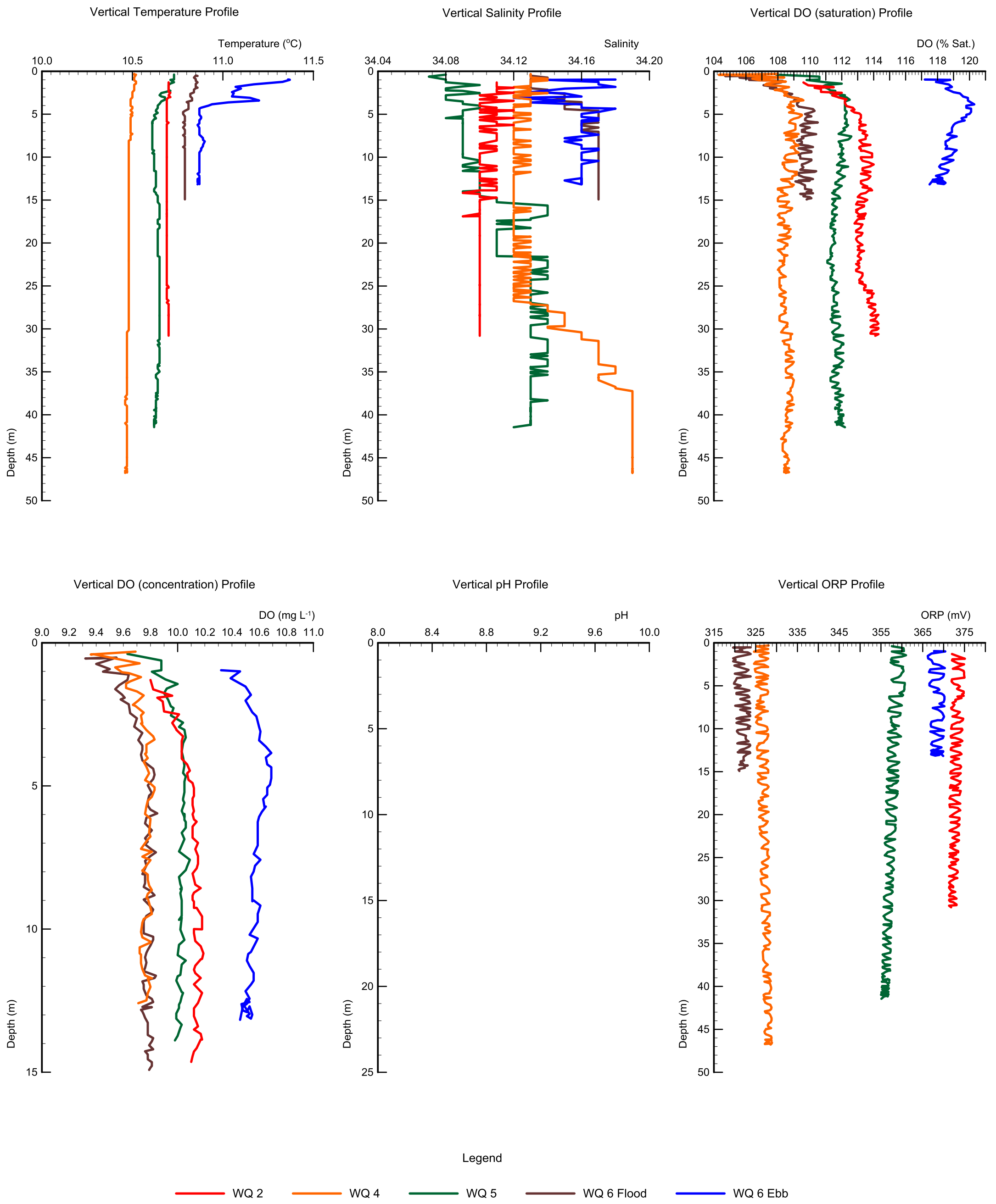


Vertical Water Column Profiles
February 2013



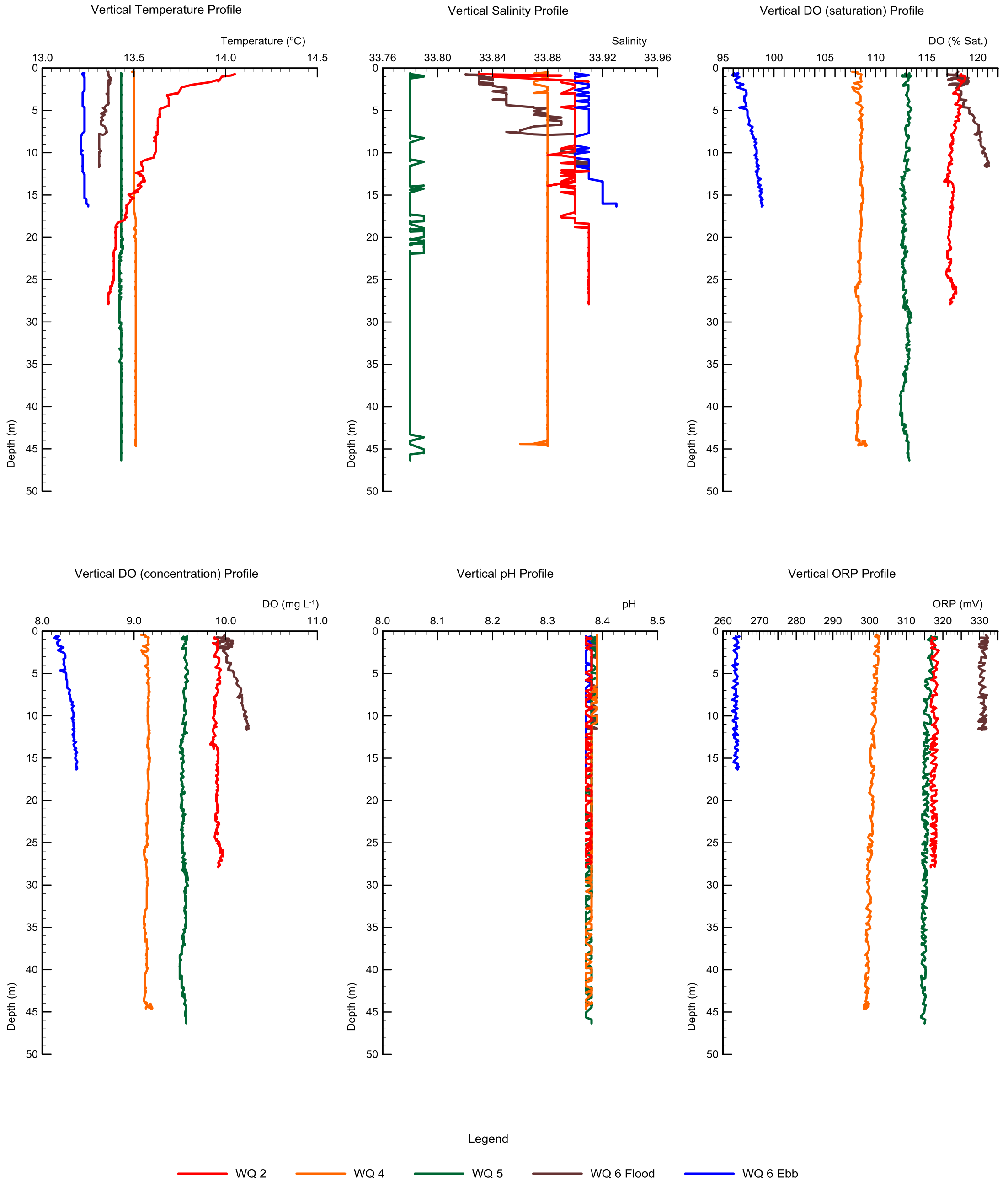
Note: ORP profiles are not available for this month. ORP sensor was not operational until later in the month.

Vertical Water Column Profiles
May 2013

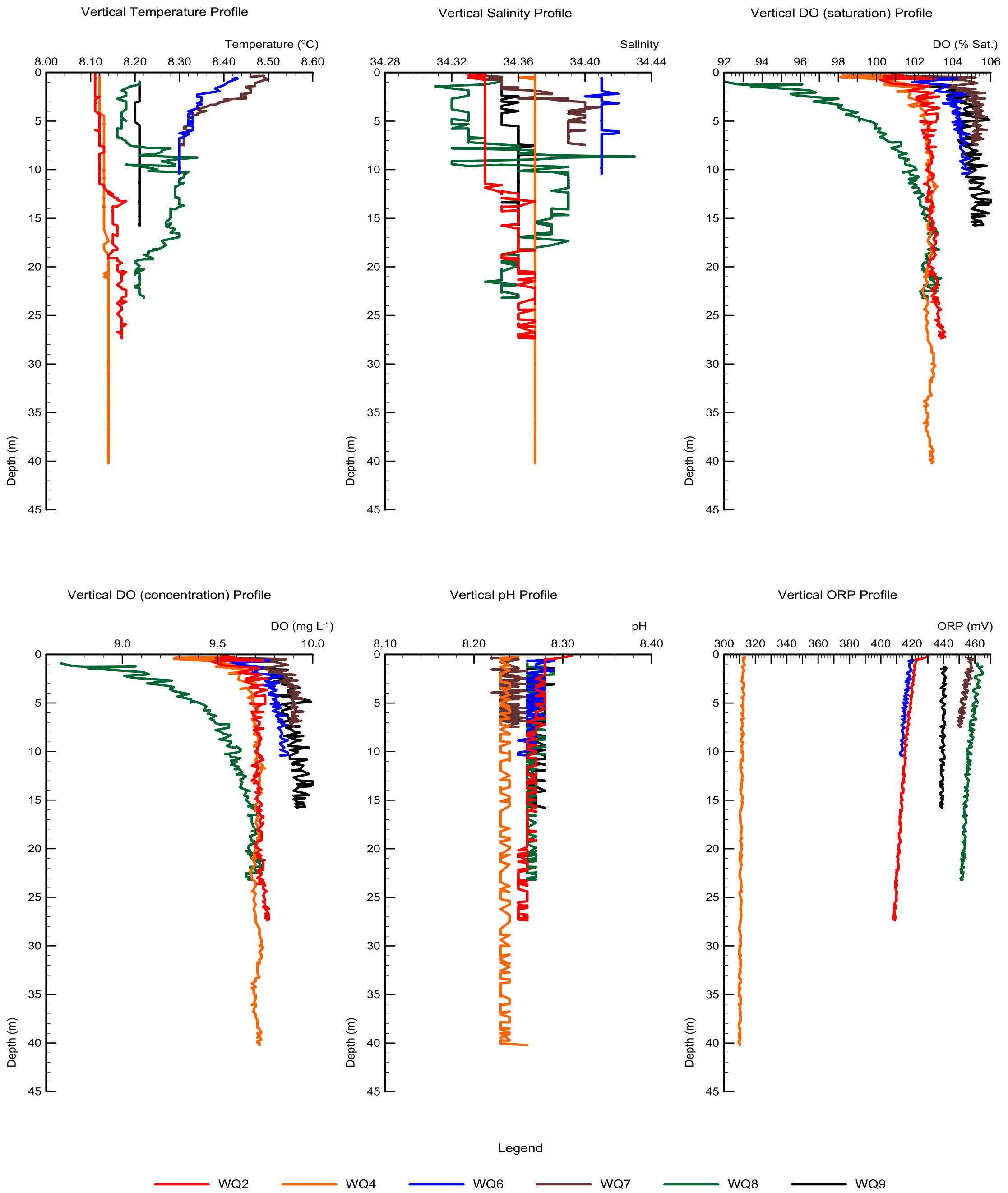


Note: Due to a technical problem with the internal configuration the pH sensor did not record decimal values, therefore vertical profiles have been disregarded (all values were recorded as 8 or 9)

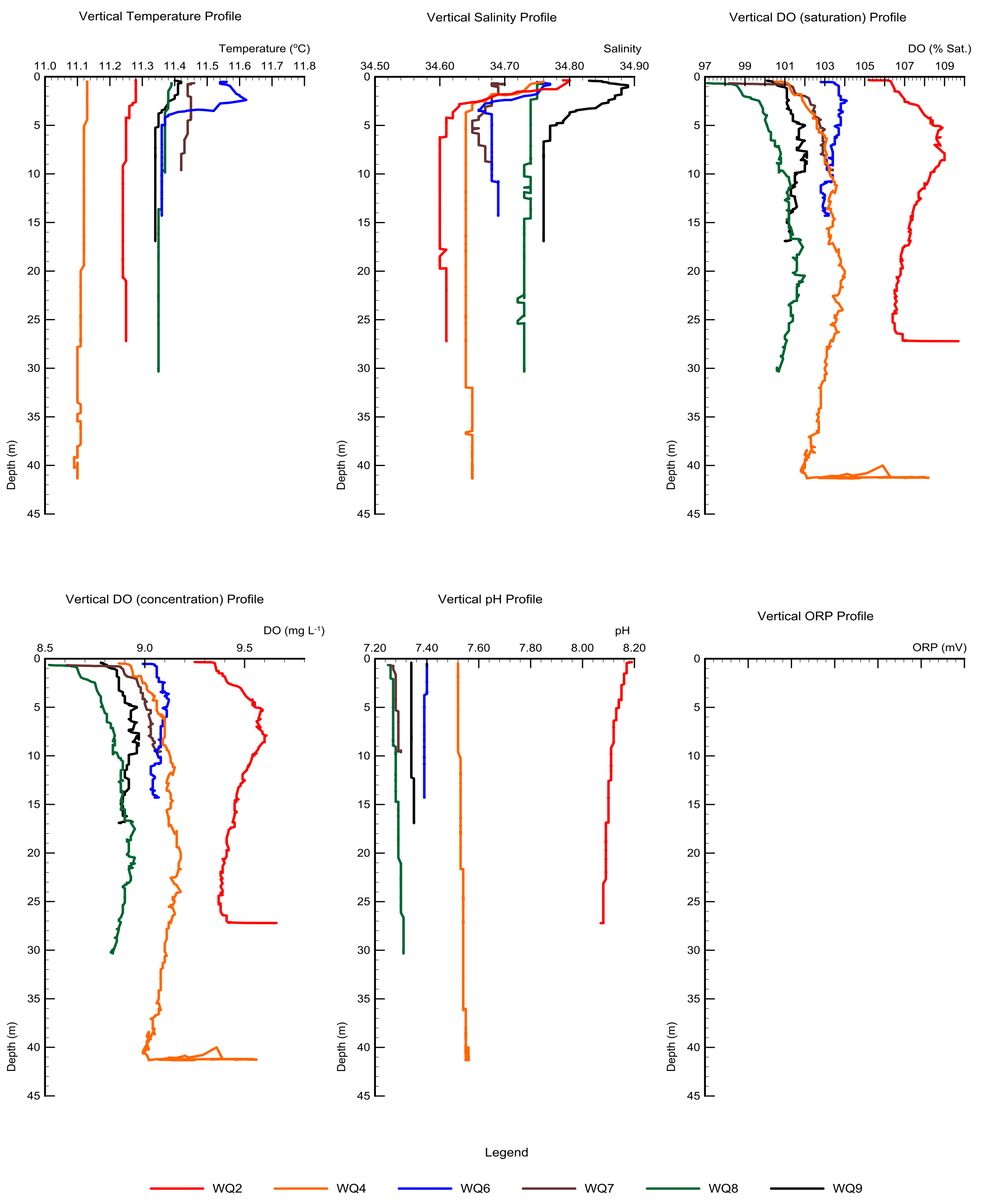
Vertical Water Column Profiles
October 2013



Vertical Water Column Profiles
March 2014

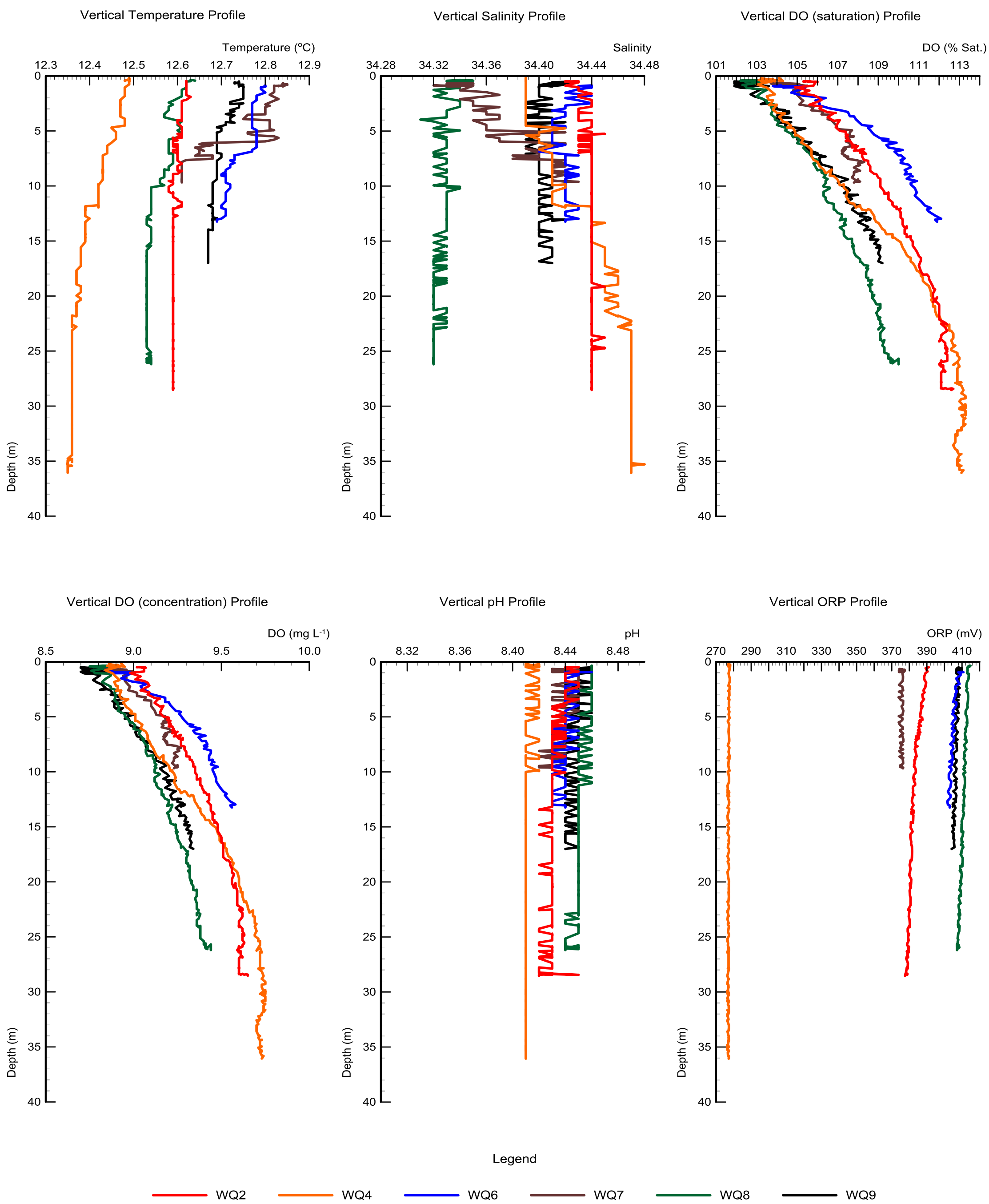


Vertical Water Column Profiles
May 2014

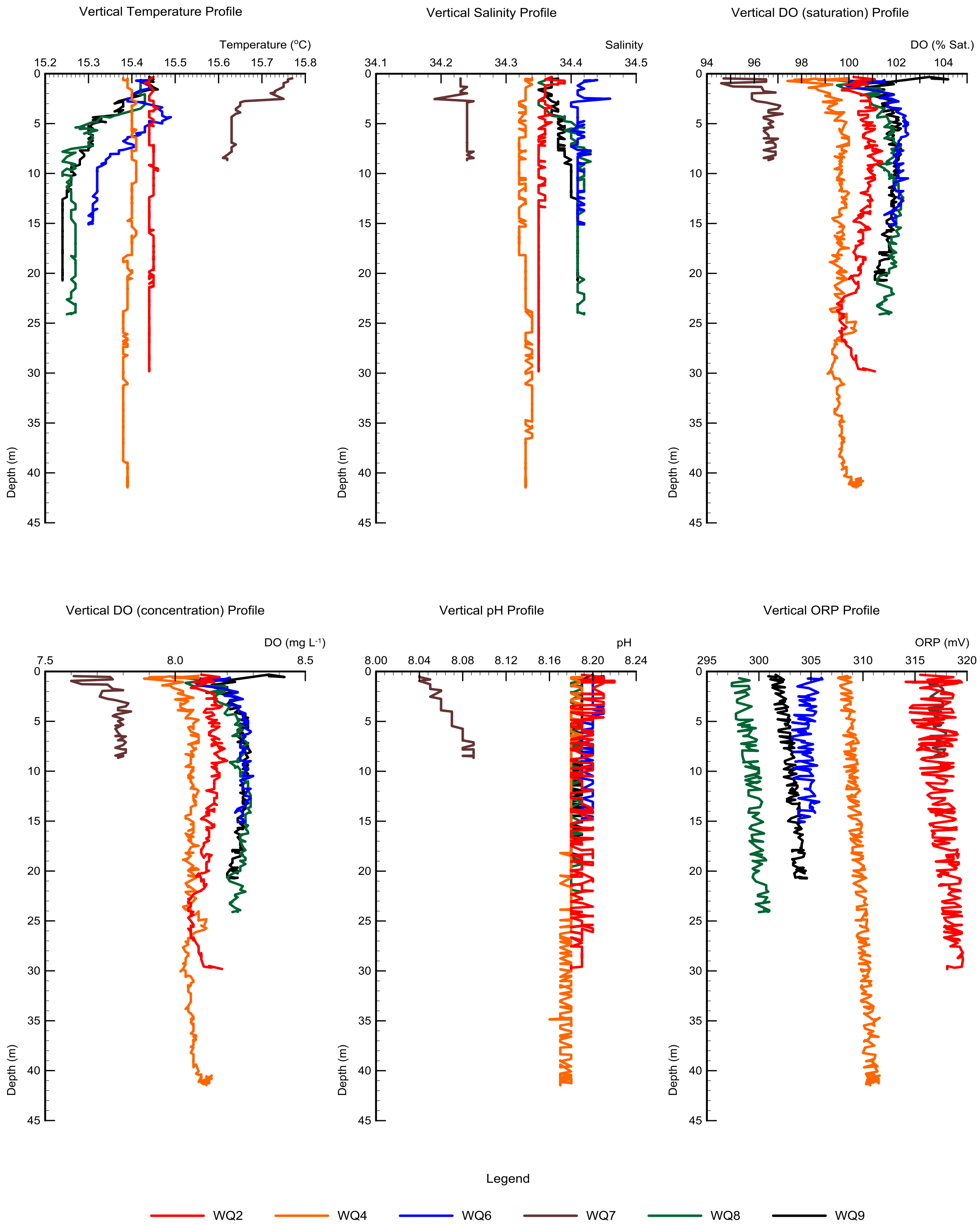


Note: ORP profiles are not available as the sonde used (YSI6600v2) was not fitted with it an ORP sensor

Vertical Water Column Profiles
June 2014



Vertical Water Column Profiles
July 2014



Appendix B. Water Quality – Monthly Variations of Water Physico-Chemical Properties

Table B.1 : Maximum, minimum and mean temperature values (°C) for the water column recorded for each survey from May 2010 to November 2014.

	Water Temperature (°C)														
Year	2010			2011			2012			2013			2014		
Month	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
January	-	-	-	7.29	6.86	7.08	9.17	8.55	8.99	-	-	-	-	-	-
February	-	-	-	7.36	6.76	6.92	7.88	7.37	7.53	8.12	6.9	7.09	7.57	7.47	7.49
March	-	-	-	7.77	7.2	7.38	8.38	8.05	8.18	6.6	6.08	6.39	8.5	8.1	8.21
April	-	-	-	9.16	9	9.07	9.57	9.01	9.17	8.16	7.45	7.75	9.18	9.16	9.16
May	9.75	9.3	9.48	11.32	11.03	11.16	10.22	9.76	9.87	11.37	10.46	10.64	11.62	11.09	11.28
June	12.61	12.52	12.57	13.21	12.68	12.9	12.88	11.55	11.95	12.37	11.7	11.99	12.85	12.35	12.58
July	15.21	14.48	14.8	16.45	14.61	14.82	14.24	13.69	13.81	14.16	13.38	13.58	15.77	15.24	15.38
August	16.6	15.36	15.95	16.32	15.84	15.95	15.39	14.98	15.14	16.12	15.56	15.76	16.84	16.28	16.47
September	15.58	15.4	15.49	15.3	14.95	15.08	15.13	14.88	15.03	15.81	15.51	15.69	16.44	16.05	16.19
October	14.64	14.41	14.58	15.13	14.79	14.85	13.97	13.73	13.87	14.05	13.21	13.44	-	-	-
November	13.13	11.45	11.77	12.94	12.48	12.77	-	-	-	-	-	-	14.01	13.73	13.91
December	8.32	7.68	8.01	-	-	-	-	-	-	-	-	-	-	-	-

Table B.2 : Maximum, minimum and mean salinity values for the water column recorded for each survey from May 2010 to November 2014.

	Water Salinity														
Year	2010			2011			2012			2013			2014		
Month	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
January	-	-	-	33.89	33.59	33.78	34.56	34.1	34.44	-	-	-	-	-	-
February	-	-	-	34.45	33.47	34.08	34.08	33.85	33.97	34.74	34.57	34.66	34.18	34.07	34.13
March	-	-	-	35.28	34.49	34.99	34.36	33.55	34.2	34.14	33.69	33.99	34.43	34.3	34.37

	Water Salinity														
Year	2010			2011			2012			2013			2014		
Month	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
April	-	-	-	34.5	34.2	34.41	33.99	33.36	33.8	34.35	34.01	34.17	34.4	34.38	34.39
May	34.31	33.7	34.04	35.29	34.72	35.13	34.1	33.19	33.85	34.19	34.07	34.13	34.89	34.6	34.69
June	33.54	33.14	33.38	34.64	34.38	34.52	33.87	33.49	33.65	34.29	34.09	34.18	34.48	34.31	34.41
July	34.4	33.34	33.94	35	34.73	34.87	34.17	33.68	34.02	34.39	34.19	34.28	34.46	34.19	34.36
August	34.19	33.33	33.81	35	34.77	34.89	34.84	33.93	34.44	34.25	34.06	34.14	34.43	34.27	34.33
September	34.29	34.08	34.21	34.5	34.25	34.38	35.24	32.8	34.99	34.2	34.03	34.1	34.5	34.28	34.35
October	34.53	33.9	34.25	34.87	34.6	34.75	34.86	34.6	34.71	33.93	33.4	33.85	-	-	-
November	34.39	33.95	34.12	34.81	34.52	34.7	-	-	-	-	-	-	34.32	34.16	34.29
December	34.55	34.1	34.37	-	-	-	-	-	-	-	-	-	-	-	-

Table B.3 : Maximum, minimum and mean dissolved oxygen saturation levels (%) of the water column recorded for each survey from May 2010 to November 2014.

	Dissolved Oxygen (% saturation)														
Year	2010			2011			2012			2013			2014		
Month	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
January	-	-	-	103	97.5	99.7	101.4	98.4	100.1	-	-	-	-	-	-
February	-	-	-	100.4	97.6	99.2	104	99.5	101.9	109.3	98.2	100.8	100.3	96.3	99
March	-	-	-	103.2	98.4	100.4	104.8	99.4	101.8	-	-	-	106	92	103.1
April	-	-	-	105.5	102.2	104.4	106.1	98.6	101.2	-	-	-	107.3	103.6	106.5
May	113.8	100.7	105.5	110.1	102.3	105	103.9	96.8	100.6	120.3	104.3	111	109.7	97.1	103.2
June	-	-	-	99.8	94.6	97.2	100.1	94.5	96.8	109.6	95	104.6	113.3	101.9	108.3
July	106.2	99.9	102.6	107	97.2	100.8	103.2	95.7	98.3	118.9	2	108.6	104.2	94.6	100.6
August	109	97.7	100.6	103.2	92.7	96.5	103.8	96.1	98.5	-	-	-	98.2	91.7	96.1
September	101.8	93	95.9	104.6	94.8	97.9	106.2	94.9	98.7	95	91.5	93.2	100.3	90.2	94.6

	Dissolved Oxygen (% saturation)														
Year	2010			2011			2012			2013			2014		
Month	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
October	106.1	95.1	99.5	102.1	95.8	98.7	105.3	93.6	96.5	121.1	95.9	112.1	-	-	-
November	106.5	95.5	98.6	108.6	94.9	98.1	-	-	-	-	-	-	117.8	90.6	91.7
December	105.1	96.4	99.6	-	-	-	-	-	-	-	-	-	-	-	-

Table B.4 : Maximum, minimum and mean dissolved oxygen concentration (mg L^{-1}) of the water column recorded for each survey from May 2010 to November 2014.

	Dissolved Oxygen (mg L^{-1})														
Year	2010			2011			2012			2013			2014		
Month	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
January	-	-	-	9.98	9.44	9.68	9.44	9.1	9.27	-	-	-	-	-	-
February	-	-	-	9.78	9.53	9.65	9.94	9.54	9.78	10.59	9.46	9.73	9.63	9.24	9.5
March	-	-	-	9.92	9.43	9.61	9.93	9.4	9.61	-	-	-	10	8.7	9.72
April	-	-	-	9.77	9.44	9.65	9.74	9.15	9.37	-	-	-	9.9	9.56	9.83
May	10.47	9.22	9.69	9.68	8.98	9.23	9.49	8.82	9.17	10.69	9.32	9.95	9.66	8.52	9.08
June	-	-	-	8.51	8.08	8.28	8.62	8.22	8.45	9.47	8.24	9.09	9.75	8.7	9.29
July	8.7	8.2	8.42	8.74	7.97	8.24	8.63	8.05	8.24	9.87	7.85	9.13	8.42	7.6	8.14
August	8.77	7.87	8.09	8.25	7.42	7.71	8.48	7.83	8.02				7.79	7.26	7.62
September	8.25	7.53	7.76	8.53	7.72	7.98	8.64	7.7	8.03	7.66	7.37	7.51	7.98	7.19	7.53
October	8.79	7.82	8.2	8.35	7.83	8.07	8.79	7.81	8.05	10.25	8.13	9.47	-	-	-
November	9.36	8.37	8.62	9.3	8.06	8.37	-	-	-	-	-	-	9.81	7.54	7.65
December	10.05	9.13	9.43	-	-	-	-	-	-	-	-	-	-	-	-

Table B.5 : Maximum, minimum and mean water pH values recorded for each survey from May 2010 to November 2014.

	Water pH														
Year	2010			2011			2012			2013			2014		
Month	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
January	-	-	-	8.2	7.96	8.01	8.09	8.02	8.06	-	-	-	-	-	-
February	-	-	-	7.84	7.68	7.78	8.06	7.98	8.02	8.23	7.86	8.09	8.25	8.2	8.21
March	-	-	-	8.41	7.79	8.33	8.11	7.89	8.05	8.32	8.23	8.27	8.31	8.2	8.26
April	-	-	-	8.26	7.76	7.9	8.2	8.02	8.15	-	-	-	8.21	8.16	8.19
May	8.34	7.78	8.19	8.24	7.98	8.13	8.14	7.96	8.04	-	-	-	8.19	7.25	7.52
June	-	-	-	7.82	6.94	7.46	8.17	7.27	7.65	-	-	-	8.46	8.41	8.43
July	8.25	7.84	8.08	8.15	7.96	8.11	8.2	7.92	8.14	8.46	8.4	8.44	8.22	8.04	8.18
August	8.18	7.92	8.14	7.94	7.69	7.86	8.13	7.97	8.05	8.43	8.33	8.38	8.32	8.28	8.29
September	8.1	7.93	8.04	-	-	-	8.19	8.12	8.15	8.42	8.37	8.39	8.36	8.3	8.31
October	8.09	7.87	8.04	8.11	7.96	8.04	8.2	8.11	8.16	8.39	8.37	8.38	-	-	-
November	8.23	7.99	8.17	8.11	7.94	8.07	-	-	-	-	-	-	8.18	7.96	8.13
December	8.15	7.86	8.07	-	-	-	-	-	-	-	-	-	-	-	-

Table B.6 : Minimum, maximum and mean chlorophyll *in vivo* concentrations (µg L^{-1}) recorded for each survey from May 2010 to October 2012.

	Chlorophyll *in vivo* (µg L^{-1})								
Year	2010			2011			2012		
Month	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
January	-	-	-	2.6	0.3	1.3	38.2	0	0.9
February	-	-	-	5.5	0.3	1.4	16.9	0.6	1.4
March	-	-	-	4.2	0	1	2.1	0.2	1.1
April	-	-	-	3.6	0.9	2	15.1	0.8	3.2
May	31.8	0.1	2.5	33.6	1.9	3.9	37.8	1.4	4.2

	Chlorophyll *in vivo* (µg L^{-1})								
Year	**2010**			**2011**			**2012**		
Month	**Max.**	**Min.**	**Mean**	**Max.**	**Min.**	**Mean**	**Max.**	**Min.**	**Mean**
June	-	-	-	35.9	0.3	1.7	7.2	0	0.7
July	71.3	0	3.4	28	0.1	1.4	5.3	0.5	1.4
August	31.1	0.6	2.7	2.5	0.5	1.4	6.1	1.1	2.3
September	7.9	0	0.7	11	0.6	1.6	16	0.1	1.8
October	13	0	1	12.9	0	0.7	12.6	0	0.9
November	10.3	0	0.6	15.6	0	0.7	-	-	-
December	2.2	0	0.2	-	-	-	-	-	-

Table B.7 : Minimum, maximum and mean turbidity values (NTU) recorded for each survey from May 2010 to October 2012.

	Turbidity (NTU)								
Year	**2010**			**2011**			**2012**		
Month	**Max.**	**Min.**	**Mean**	**Max.**	**Min.**	**Mean**	**Max.**	**Min.**	**Mean**
January	-	-	-	10.3	5	6.8	12.8	4.7	8.6
February	-	-	-	14.1	2.2	5.7	11.8	5.5	9.9
March	-	-	-	6.5	1.2	2.5	9.3	3.8	6.7
April	-	-	-	5.1	0.9	2.1	5.8	0	1.4
May	12	0	1.7	12.6	0.9	4.7	10	0.5	3.3
June	-	-	-	9.5	0.2	2.1	5.6	0	1.2
July	7.1	0.6	3.2	28	0.1	1.4	5.5	1	2.2
August	9.3	0	1.3	4.1	1.4	2.5	10.6	0.8	2.9
September	7.6	2.9	4.9	10.9	0	0.9	8.2	1	4.8
October	6.6	0	2.3	5.3	0.6	3.4	2.4	0.2	1.2
November	11.4	1	4.5	5.6	2.2	3.8	-	-	-

	Turbidity (NTU)								
Year	2010			2011			2012		
Month	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
December	30	0	0.8	-	-	-	-	-	-

Table B.8 : Minimum, maximum and mean ORP or Redox values (mV) recorded for each survey from March 2013 to November 2014.

	Water ORP (mV)					
Year	2013			2014		
Month	Max.	Min.	Mean	Max.	Min.	Mean
January	-	-	-	-	-	-
February	-	-	-	373.7	329.6	354.8
March	439.9	398.6	417.3	464.8	309.4	404.2
April	-	-	-	291.1	288.7	289.5
May	375.1	319.6	347.7	-	-	-
June	413.8	370	395.9	414.8	276.4	366.3
July	374.5	321.8	360.7	319.6	297.4	309.1
August	-	-	-	381.3	287.4	311.9
September	427.4	388.3	399.5	391.2	305.3	347
October	332.3	262.5	309	-	-	-
November	-	-	-	-	-	-
December	-	-	-	-	-	-

Appendix C. Water Quality – Statistical Analysis on Results Reported from May 2010 to April 2011

Hydrocarbons, some metals, the majority of nutrients and physico-chemical determinands were not included in statistical analysis as they were predominantly below the limit of detection, with little or no variation between samples within the same month.

(a) Cations and anions

All cations and anions were included in this analysis. To examine any differences in the anions and cations recorded between tides (ebb vs. flood), depth (surface vs. mid-depth) or sampling sites a two-way crossed ANOSIM test (depth vs. site) and a one-way ANOSIM (tides only) were applied to the data. There were no significant differences between samples from different tidal states (ebb vs. flood) (R = -0.003, p = 0.752), from different depths (surface vs. mid-depth) (R = -0.019, p = 0.248) or from different sites (Global R = -0.021 p = 0.978).

A one-way ANOSIM indicated significant differences between sampling months (Global R = 0.521, p = 0.01). Pairwise comparisons showed that in most cases the R values were low, indicating substantial overlap in sample similarity between months. Bigger differences occurred between late spring/summer months compared with late autumn/winter months. The principal components analysis (PCA) plot for the anion and cation concentrations shows the samples to be loosely clustered within most months but for individual months to overlap with one another and remain in close proximity much of the time (Figure C.1). In fact, most of the samples were clustered away from the direction of the determinands vectors suggesting strong similarity between the samples.

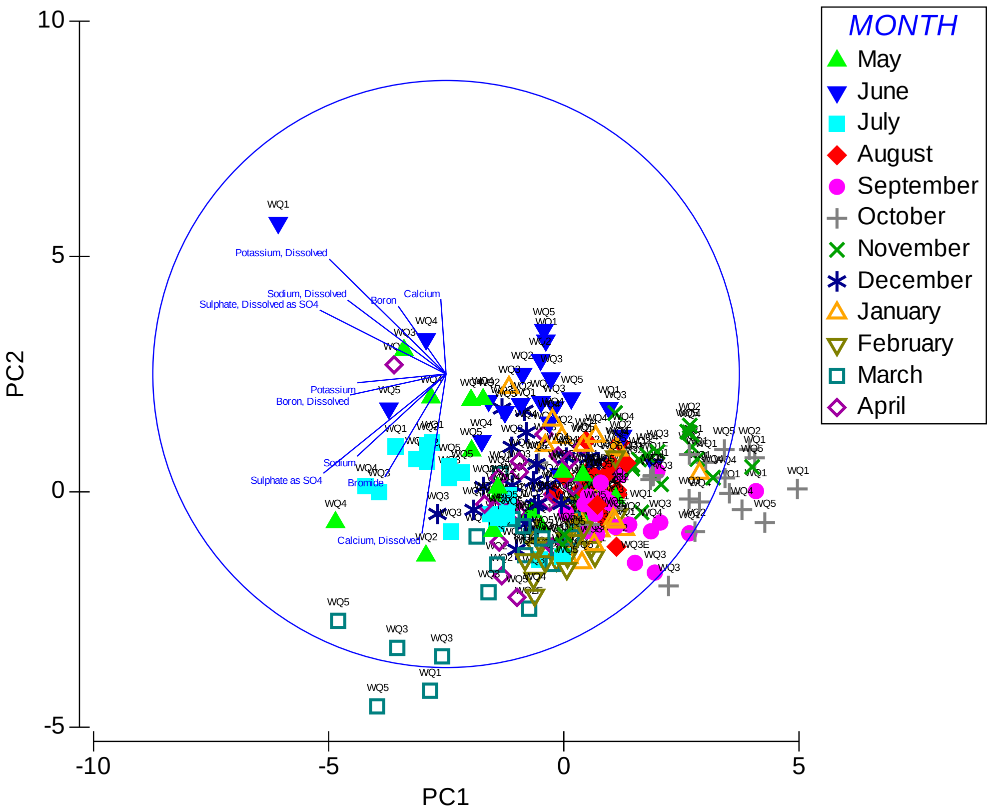


Figure C.1 : PCA plot of anions and cations data displayed by sampling month, obtained from seawater samples from north Anglesey between May 2010 and April 2011.

(b) Nutrients

Most of the nutrients analysed were at or below the limits of detection and therefore no differences were apparent between any of the sites sampled or the flood and ebb tide samples. Only dissolved organic carbon (DOC), total organic carbon (TOC), nitrogen as N (N) and total suspended solids (TSS) showed any regular readings above the limit of detection.

Data for each of these determinands were pooled for the whole year. The data were not normally distributed and therefore the non-parametric Kruskal-Wallis test was used to analyse for any differences between sampling sites and tidal states. For each of the four determinands (DOC, TOC, N and TSS) the tests showed no significant differences between sampling sites or tidal states over the entire year in every single test conducted ($p > 0.05$ in all cases).

(c) Metals

Metals included in this analysis were arsenic, boron, copper, lead, nickel and zinc. The remaining metal compounds (selenium, cobalt, tin, vanadium, cadmium, manganese, mercury and chromium) were not used in the statistical analysis as they were rarely recorded above the limit of detection and would therefore have been regarded as the same across all samples.

To examine any differences in the metal concentrations reported between tides (ebb vs. flood), depth (surface vs. mid-depth) or sampling sites, a two-way crossed ANOSIM test (depth vs. site) and a one-way ANOSIM (tides only) were applied to the data. There were no significant differences between samples from different tidal states (ebb vs. flood) ($R = 0.002$, $p = 0.24$), from different depths (surface vs. mid-depth) ($R = 0.006$, $p = 0.248$) or from different sites (Global $R = 0.035$, $p = 0.4$).

A one-way ANOSIM indicated significant differences between sampling months (Global $R = 0.35$, $p = 0.001$). Pairwise comparisons showed that in most cases the R values were very low, indicating substantial overlap in sample similarity between months. Bigger differences occurred between spring/summer months compared with autumn/winter months or between samples taken a year apart e.g. May 2010 compared with April 2011. The PCA plot for metal concentrations shows samples to be clustered within most months but to overlap with one another for individual months and remain in close proximity much of the time (Figure C.2). Indeed, most of the samples were clustered away from the direction of the determinands vectors suggesting generally low concentrations of metals in most samples with occasional higher values in samples away from the main cluster.

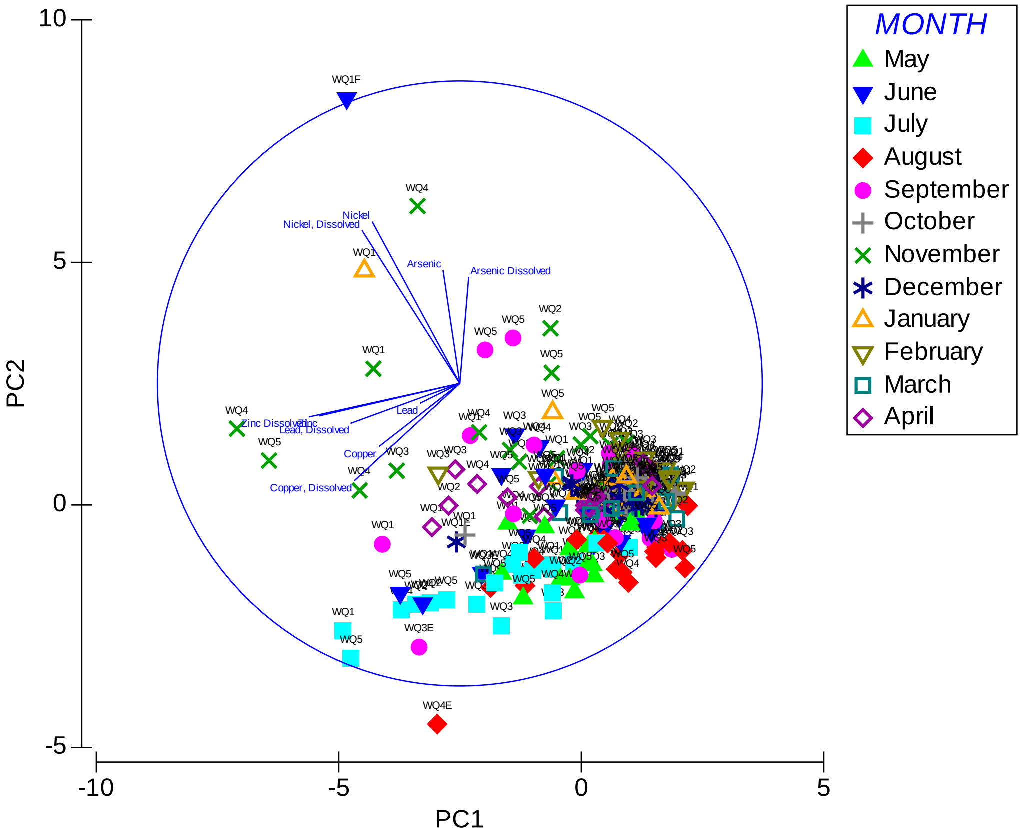


Figure C.2 : PCA plot of metal, carbon and nitrogen concentration data displayed by sampling month, obtained from seawater samples from north Anglesey between May 2010 and April 2011.

Appendix D. Water Quality – Laboratory Analysis Results. Annual Averages

This Appendix presents the annual average for each calendar year. It must be noted that depending on the year, the annual average is based on 12 months or less. Please refer to Section 3.2.2 for further details. The annual average has been presented as a way to summarise all data available.

Table D.1 : Physico-chemical properties. MRVs and Annual Average reported between 2010 and 2014. Compounds shaded in grey were not monitored in that particular year.

Compound	*Units*	*MRV*	2010	2011	2012	2013	2014
pH	pH Units	0.05	8.07	8.04	8.04	8.03	8.12
Alkalinity to pH 4.5 as $CaCO_3$	mg L^{-1}	5	73.30	74.78	75.01	74.82	-
BOD 5 Day ATU	mg L^{-1}	1	<2.90	1.45	1.25	<1.00	-
Chemical Oxygen Demand {COD}	mg L^{-1}	300	342	<500	<500	<500	-
Organic Carbon: Dissolved as C {DOC}	mg L^{-1}	0.2	1.39	1.30	1.23	-	1.40
Organic Carbon: Total as C {TOC}	mg L^{-1}	1	1.25	4.47	1.26	-	1.28
Suspended Solids at 105 ºC	mg L^{-1}	3	6.41	6.13	7.12	-	13.04

Table D.2 : Cations and Anions concentrations. MRVs, Annual Average reported between 2010 and 2014. Compounds shaded in grey were not monitored in that particular year.

Compound	*Units*	*MRV*	2010	2011	2012	2013	2014
Bromide	mg L^{-1}	0.05	66.1	68.2	68.3	-	64.5
Calcium	mg L^{-1}	10	399	403	413	-	-
Calcium, Dissolved	mg L^{-1}	10	392	404	414	-	409
Potassium	mg L^{-1}	1	374	377	368	-	-
Potassium, Dissolved	mg L^{-1}	1	372	377	363	-	389
Sodium	mg L^{-1}	20	10128	10481	10466	-	-
Sodium, Dissolved	mg L^{-1}	20	10078	10478	10372	-	9929
Sulphate as SO_4	mg L^{-1}	5	2548	2623	2659	-	-
Sulphate, Dissolved as SO_4	mg L^{-1}	5	2565	2637	2626	-	2535

Table D.3 : Nutrients concentrations. MRVs, EQSs and Annual Average reported between 2010 and 2014. Compounds shaded in grey were not monitored in that particular year.

Compound	Units	MRV	EQS	2010	2011	2012	2013	2014
Orthophosphate as P (Filtered)	mg L^{-1}	0.01	n/a	0.020	0.021	0.021	0.019	0.015
Silicate as SiO_2 (Filtered)	mg L^{-1}	0.2	n/a	<0.2	<0.2	0.218	<0.200	0.243
Nitrate as N (Filtered)	mg L^{-1}	n/a	n/a	<0.1	<0.1	<0.1	<0.1	<0.1
Nitrite as N (Filtered)	mg L^{-1}	0.004	n/a	0.0046	0.005	<0.004	<0.00400	0.0061
Nitrogen as N	mg L^{-1}	0.1	n/a	0.126	0.170	0.195	-	0.256
Nitrogen, Total Oxidised as N (Filtered)	mg L^{-1}	0.1	n/a	<0.1	<0.100	<0.100	<0.100	<0.1
Nitrogen, Total Oxidised as N	mg L^{-1}	0.2	n/a	<0.200	<0.200	<0.100	-	-
Nitrogen : Total Organic as N	mg L^{-1}	n/a	n/a	<0.986	<0.985	<0.980	-	<0.973
Nitrogen : Inorganic, Filtered as N	mg L^{-1}	n/a	n/a	<0.21	<0.21	<0.120	<0.120	<0.120
Nitrogen, Kjeldahl as N	mg L^{-1}	n/a	n/a	<1.00	<1.00	<1.00	-	<1.00
Ammoniacal Nitrogen as N (Filtered)	mg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	<0.0200	<0.0200
Ammoniacal Nitrogen as N	mg L^{-1}	0.01	n/a	0.035	<0.01	<0.02	-	-
Ammonia un-ionised as N	µg L^{-1}	n/a	21	<0.476	<0.504	<0.435	<0.472	<0.958

Note: Values reported in red were calculated in house using the same algorithm than the laboratory and not reported directly by the laboratory.

Table D.4 : Metals. MRVs, EQSs and Annual Average reported between 2010 and 2014. Compounds shaded in grey were not monitored in that particular year.

Compound	Units	MRV	EQS	2010	2011	2012	2013	2014
Arsenic, Total	µg L^{-1}	1	25	1.57	1.53	1.52	-	-
Arsenic, Dissolved	µg L^{-1}	1	25	1.43	1.42	1.53	-	1.41
Copper, Total	µg L^{-1}	0.2	5	0.95	0.87	0.92	-	-
Copper, Dissolved	µg L^{-1}	0.2	5	0.82	0.60	0.64	-	0.73
Lead, Total	µg L^{-1}	0.04	7.2	0.62	0.81	0.93	-	-
Lead, Dissolved	µg L^{-1}	0.04	7.2	0.32	0.31	0.22	-	0.42
Nickel, Total	µg L^{-1}	0.3	20	0.46	0.49	0.57	-	-

Compound	*Units*	*MRV*	*EQS*	2010	2011	2012	2013	2014
Nickel, Dissolved	µg L^{-1}	0.3	20	0.42	0.37	0.36	-	0.44
Zinc, Total	µg L^{-1}	0.4	40	6.49	5.85	6.54	-	-
Zinc, Dissolved	µg L^{-1}	0.4	40	6.35	5.31	5.32	-	7.87
Boron, Total	µg L^{-1}	700	7000	4754	4740	4745	-	-
Boron, Dissolved	µg L^{-1}	700	7000	4736	4800	4713	-	4367
Mercury, Total (*)	µg L^{-1}	0.01	0.05*	0.016	<0.01	<0.01	-	<0.01
Mercury, Dissolved	µg L^{-1}	0.01	0.05*	<0.01	<0.01	<0.01	-	<0.01
Chromium, Total	µg L^{-1}	0.5	15	0.372	0.61	<0.5	-	-
Chromium, Dissolved	µg L^{-1}	0.5	15	1.069	0.58	<0.5	-	<0.5
Cadmium, Total	µg L^{-1}	0.04	0.2	<0.04	<0.04	<0.04	-	-
Cadmium, Dissolved	µg L^{-1}	0.04	0.2	<0.04	<0.04	<0.04	-	<0.03
Selenium, Total	µg L^{-1}	1	n/a	<1	<1.00	<1.00	-	-
Selenium, Dissolved	µg L^{-1}	1	n/a	<1	<1.00	<1.00	-	<1
Cobalt, Total	µg L^{-1}	10	3**	<10	<10	<10	-	-
Cobalt, Dissolved	µg L^{-1}	10	3**	<10	<10	<10	-	<10
Tin, Total	µg L^{-1}	25	10**	<25	<20	<20	-	-
Tin, Dissolved	µg L^{-1}	25	10**	<25	<20	<20	-	<20
Vanadium, Total	µg L^{-1}	20	100	<20	<20	<20	-	-
Vanadium, Dissolved	µg L^{-1}	20	100	<20	<20	<20	-	<20
Manganese, Total	µg L^{-1}	20	n/a	<20	<20	<20	-	-
Manganese, Dissolved	µg L^{-1}	20	n/a	<20	<20	<20	-	<20
Iron, Dissolved	µg L^{-1}	100	1000	-	-	-	-	<100

* According to 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 EQS should be calculated from biota samples (20 µg Kg^{-1} of prey tissue). Nevertheless, regulatory bodies in England and Wales still use the mercury EQS stated in this report as guidance for other purposes.

** These EQSs for List II substances have been initially proposed through research programmes run by Defra and other regulatory bodies (such as the Environment Agency), based on a critical assessment of all the available data. While they remain non-statutory, they are used by regulatory bodies.

Table D.5 : TPHs, PCBs and PAHs. MRVs, EQSs and Annual Average reported between 2010 and 2014. Compounds shaded in grey were not monitored in that particular year.

Compound	Units	MRV	EQS	2010	2011	2012	2013	2014
Hydrocarbons Screen >C5 - C44	mg L^{-1}	0.2	n/a	<0.2	<0.2	<0.2	-	<0.2
PCB 008	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 020	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 028	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 031	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 035	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 052	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 077	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 101	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 105	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 118	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 126	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 128	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 138	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 149	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 153	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 156	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 169	µg L^{-1}	0.001	n/a	<0.001	<0.001	<0.001	-	<0.001
PCB 170	µg L^{-1}	0.001	n/a	<0.001	<0.002	<0.002	-	<0.002
PCB 180	µg L^{-1}	0.001	n/a	<0.001	<0.002	<0.002	-	<0.002
Acenaphthene	µg L^{-1}	0.01	n/a	<0.01	<0.01	<0.01	-	<0.01
Acenaphthylene	µg L^{-1}	0.01	n/a	<0.01	<0.01	<0.01	-	<0.01

Compound	*Units*	*MRV*	*EQS*	2010	2011	2012	2013	2014
Anthracene	µg L^{-1}	0.01	0.1	<0.01	<0.01	<0.01	-	<0.01
B(a)anthracene	µg L^{-1}	0.01	n/a	<0.01	<0.01	<0.01	-	<0.01
B(a)pyrene	µg L^{-1}	0.01	0.05	<0.01	<0.01	<0.01	-	<0.01
B(b)fluoranthene	µg L^{-1}	0.01	0.03	<0.01	<0.01	<0.01	-	<0.01
B(e)pyrene	µg L^{-1}	0.01	n/a	<0.01	<0.01	<0.01	-	<0.01
B(ghi)perylene	µg L^{-1}	0.01	0.002	<0.01	<0.01	<0.01	-	<0.01
B(k)fluoranthene	µg L^{-1}	0.01	0.03	<0.01	<0.01	<0.01	-	<0.01
Chrysene	µg L^{-1}	0.01	n/a	<0.01	<0.01	<0.01	-	<0.01
DiB(ah)anthracene	µg L^{-1}	0.01	n/a	<0.01	<0.01	<0.01	-	<0.01
Fluoranthene	µg L^{-1}	0.01	n/a	<0.01	<0.01	<0.01	-	<0.01
Fluorene	µg L^{-1}	0.01	n/a	<0.01	<0.01	<0.01	-	<0.01
Indeno(1,2,3-cd)Pyrene	µg L^{-1}	0.01	0.002	<0.01	<0.01	<0.01	-	<0.01
Naphthalene	µg L^{-1}	0.01	1.2	<0.01	<0.01	<0.01	-	<0.01
Perylene	µg L^{-1}	0.01	n/a	<0.01	<0.01	<0.01	-	<0.01
Phenanthrene	µg L^{-1}	0.01	n/a	<0.01	<0.01	<0.01	-	<0.01
Pyrene	µg L^{-1}	0.01	n/a	<0.01	<0.01	<0.01	-	<0.01

Table D.6 : VOCs. MRVs, EQSs, Annual Average reported between 2010 and 2014. Compounds shaded in grey were not monitored in that particular year.

Compound	*Units*	*MRV*	*EQS*	2010	2011	2012	2013	2014
1,1,1,2-Tetrachloroethane	µg L^{-1}	0.1	n/a	-	-	-	-	<0.1
1,1,1-Trichloroethane	µg L^{-1}	0.1	100	<0.10	<0.1	<0.1	-	<0.1
1,1,2,2-Tetrachloroethane	µg L^{-1}	0.1	n/a	-	-	-	-	<0.1
1,1,2-Trichloroethane	µg L^{-1}	0.5	300	<0.50	<0.5	<0.5	-	<0.1
1,1-Dichloroethane	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
1,1-Dichloroethylene :- {1,1-Dichloroethene}	µg L^{-1}	0.5	n/a	<0.10	<0.1	<0.1	-	<0.1

Compound	*Units*	*MRV*	*EQS*	2010	2011	2012	2013	2014
1,1-Dichloropropylene :- {1,1-Dichloropropene}	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
1,2,3-Trichlorobenzene	µg L^{-1}	0.1	n/a	-	-	-	-	<0.5
1,2,3-Trichloropropane	µg L^{-1}	0.5	n/a	<0.50	<0.5	<0.5	-	<0.5
1,2,3-Trimethylbenzene	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
1,2,4-Trichlorobenzene	µg L^{-1}	0.1	n/a	-	-	-	-	<0.5
1,2,4-Trimethylbenzene	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
1,2-Dibromo-3-chloropropane	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
1,2-Dibromoethane	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
1,2-Dichlorobenzene	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
1,2-Dichloroethane	µg L^{-1}	0.1	10	<0.10	<0.1	<0.1	-	<0.1
1,2-Dichloropropane	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
1,2-Dimethylbenzene :- {o-Xylene}	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
1,3,5-Trichlorobenzene	µg L^{-1}	0.1	n/a	-	-	-	-	<0.5
1,3,5-Trimethylbenzene :- {Mesitylene}	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
1,3-Dichlorobenzene	µg L^{-1}	0.5	n/a	<0.50	<0.5	<0.5	-	<0.5
1,3-Dichloropropane	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
1,4-Dichlorobenzene	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
2,2-Dichloropropane	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
2-Chlorotoluene :- {1-Chloro-2-methylbenzene}	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
3-Chlorotoluene :- {1-Chloro-3-methylbenzene}	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
4-Chlorotoluene :- {1-Chloro-4-methylbenzene}	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
4-Isopropyltoluene :- {4-methyl-Isopropylbenzene}	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
Benzene	µg L^{-1}	0.1	50	<0.10	<0.1	<0.1	-	<0.1
Bromobenzene	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
Bromochloromethane	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1

Compound	Units	MRV	EQS	2010	2011	2012	2013	2014
Bromodichloromethane	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
Bromoform :- {Tribromomethane}	µg L^{-1}	0.1	20	<0.10	<0.1	0.12	-	<0.1
Carbon Disulphide	µg L^{-1}	0.1	n/a	-	-	-	-	<0.1
Carbon tetrachloride :- {Tetrachloromethane}	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
Chlorobenzene	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
Chlorodibromomethane	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
Chloroform :- {Trichloromethane}	µg L^{-1}	0.1	2.5	<0.10	<0.1	<0.1	-	<0.1
Chloromethane :- {Methyl Chloride}	µg L^{-1}	0.1	n/a	-	-	-	-	<0.5
Dibromomethane	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
Dichloromethane :- {Methylene Dichloride}	µg L^{-1}	0.5	20	<0.50	<3	<3	-	<0.5
DiMeBenzene 13+14	µg L^{-1}	0.2	n/a	<0.20	<0.2	<0.2	-	<0.2
Ethyl tert-butyl ether :- {ETBE}	µg L^{-1}	0.1	n/a	-	-	-	-	<0.1
Ethylbenzene	µg L^{-1}	0.1	20	<0.10	<0.1	<0.1	-	<0.1
Hexachlorobutadiene	µg L^{-1}	0.1	0.1	-	-	-	-	<0.5
Hexachloroethane	µg L^{-1}	0.1	n/a	-	-	-	-	<0.5
Isopropylbenzene	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
MTBE :- {Methyl tert-butyl ether}	µg L^{-1}	0.1	n/a	-	-	-	-	<0.1
Styrene :- {Vinylbenzene}	µg L^{-1}	0.1	50	<1.00	<0.1	<0.1	-	<0.5
Tetrachloroethylene :- {Perchloroethylene}	µg L^{-1}	0.1	10	<0.10	<0.1	<0.1	-	<0.1
Toluene :- {Methylbenzene}	µg L^{-1}	0.1	40	<0.10	<0.1	<0.1	-	<0.1
Trichloroethylene :- {Trichloroethene}	µg L^{-1}	0.1	10	<0.10	<0.1	<0.1	-	<0.1
Trichlorofluoromethane	µg L^{-1}	0.1	n/a	-	-	-	-	<0.1
Vinyl Chloride :- {Chloroethylene}	µg L^{-1}	0.1	n/a	-	-	-	-	<0.1
cis-1,2-Dichloroethylene :- {cis-1,2-Dichloroethene}	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
cis-1,3-Dichloropropylene :- {cis-1,3-Dichloropropene}	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1

Compound	Units	MRV	EQS	2010	2011	2012	2013	2014
n-ButylBenzene :- {1-Phenylbutane}	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
n-Propylbenzene :- {1-phenylpropane}	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
sec-Butylbenzene :- {1-Methylpropylbenzene}	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
tert-Amyl methyl ether :- {TAME}	µg L^{-1}	0.1	n/a	-	-	-	-	<0.1
tert-Butylbenzene :- {(1,1-Dimethylethyl)benzene}	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
trans-1,2-Dichloroethylene :- {trans-1,2-Dichloroethene}	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.1
trans-1,3-Dichloropropylene :- {trans-1,3-Dichloropropene}	µg L^{-1}	0.1	n/a	<0.10	<0.1	<0.1	-	<0.5
Di-2-ethylhexyl phthalate :- {DEHP}	µg L^{-1}	0.2	1.3	-	-	-	-	<0.400

Table D.7 : Phenols. MRVs, EQSs, Annual Average reported between 2010 and 2014. Compounds shaded in grey were not monitored in that particular year.

Compound	Units	MRV	EQS	2010	2011	2012	2013	2014
2,3,5,6-Tetrachlorophenol	µg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	-	<0.02
2,3-Dichlorophenol	µg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	-	<0.02
2,3-Dimethylphenol :- {2,3-Xylenol}	µg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	-	<0.02
2,4,5-Trichlorophenol	µg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	-	<0.02
2,4,6-Trichlorophenol	µg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	-	<0.02
2,4-Dichlorophenol	µg L^{-1}	0.02	20	<0.02	<0.02	<0.02	-	<0.02
2,4-Dimethylphenol :- {2,4-Xylenol}	µg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	-	<0.02
2,5-Dichlorophenol	µg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	-	<0.02
2,5-Dimethylphenol :- {2,5-Xylenol}	µg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	-	<0.02
2,6-Dichlorophenol	µg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	-	<0.02
2,6-Dimethylphenol :- {2,6-Xylenol}	µg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	-	<0.02
2-Chlorophenol	µg L^{-1}	0.02	50	<0.02	<0.02	<0.02	-	<0.02
2-Ethylphenol	µg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	-	<0.02
2-Methylphenol :- {o-Cresol}	µg L^{-1}	0.02	100	<0.02	<0.02	<0.02	-	<0.02

Compound	*Units*	*MRV*	*EQS*	2010	2011	2012	2013	2014
3,4-Dimethylphenol :- {3,4-Xylenol}	µg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	-	<0.02
3,5-Dimethylphenol :- {3,5-Xylenol}	µg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	-	<0.02
3-Chlorophenol	µg L^{-1}	0.02	50	<0.02	<0.02	<0.02	-	<0.02
3-Methylphenol :- {m-Cresol}	µg L^{-1}	0.02	100	<0.02	<0.02	<0.02	-	<0.02
4-Chloro-2-methylphenol :- {p-Chloro-o-cresol}	µg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	-	<0.02
4-Chloro-3,5-dimethylphenol :- {PCMX}	µg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	-	<0.02
4-Chloro-3-methylphenol :- {p-Chloro-m-cresol}	µg L^{-1}	0.02	40	<0.02	0.058	0.060	-	<0.02
4-Chlorophenol	µg L^{-1}	0.02	50	<0.02	<0.02	<0.02	-	<0.02
4-Methylphenol :- {p-cresol}	µg L^{-1}	0.02	100	<0.03	<0.02	<0.02	-	<0.02
Pentachlorophenol	µg L^{-1}	0.02	0.4	<0.02	<0.02	<0.02	-	<0.02
Phenol	µg L^{-1}	0.05	7.7	0.136	0.101	0.071	-	0.062

Table D.8 : Anticorrosive and CBPs. MRVs, EQSs, Annual Average reported in 2012 and 2013.

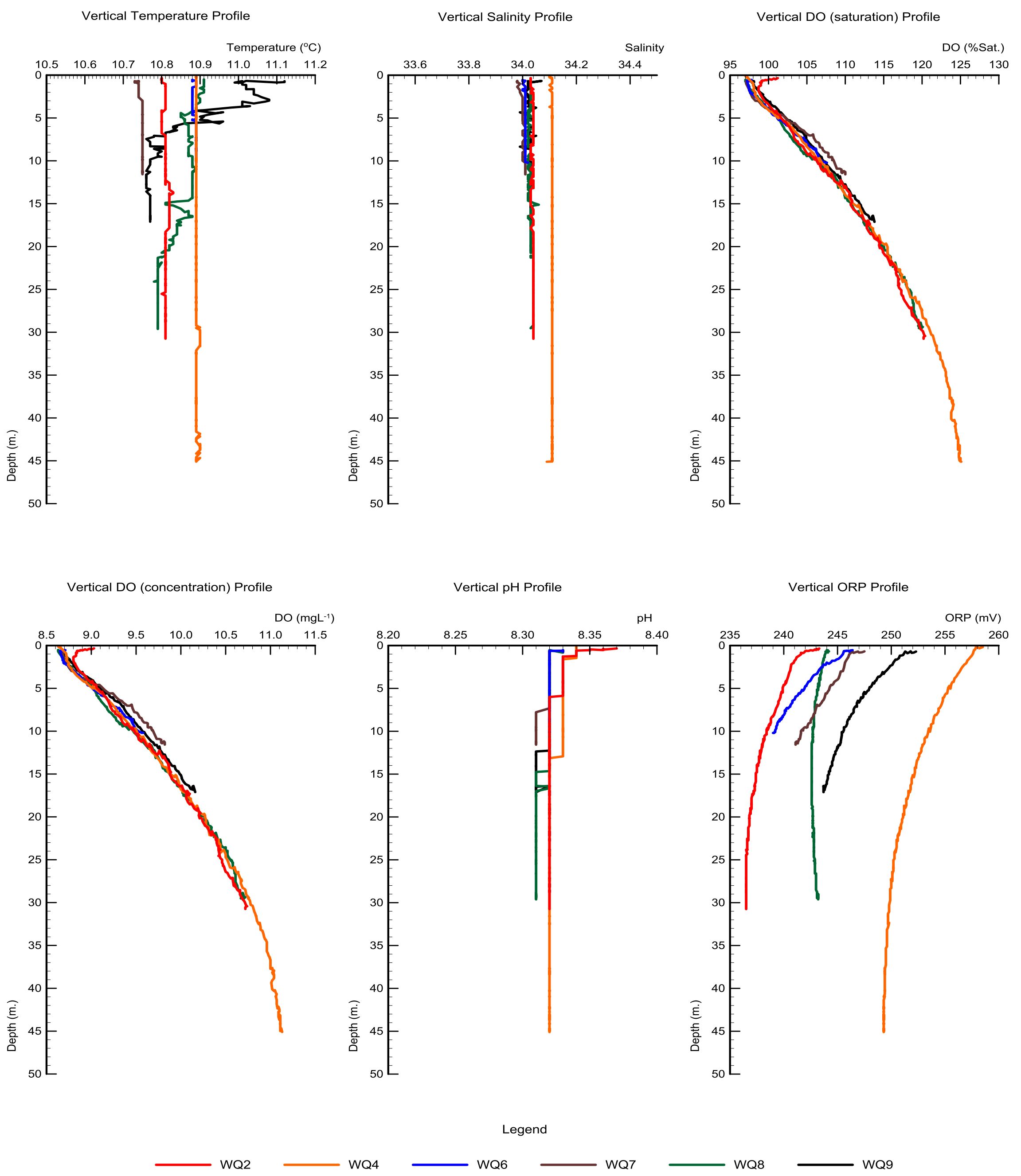
Compound	*Units*	*MRV*	*EQS*	2012	2013
Hydrazine	µg L^{-1}	0.10	n/a	<0.1	<0.1
Ethanolamine	µg L^{-1}	0.10	n/a	<0.1	<0.1
Morpholine	µg L^{-1}	0.10	n/a	<0.1	<0.1
Trichloromethane (Chloroform)	ng L^{-1}	1.00	2500	10.69	19.4
Bromodichloromethane	ng L^{-1}	1.00	n/a	3.35	6.0
Dibromochloromethane	ng L^{-1}	1.00	n/a	<1.0	<1.0
Tribromomethane (Bromoform)	ng L^{-1}	1.00	n/a	6.32	16.3
Dibromoacetonitrile	ng L^{-1}	1.00	n/a	<1.0	<1.0
Dichloroacetonitrile	ng L^{-1}	1.00	n/a	<1.0	<1.0
Trichlorophenol	ng L^{-1}	1.00	n/a	<1.0	<1.0
2,4,6-Tribromophenol	ng L^{-1}	1.00	n/a	<1.0	<1.0

Compound	Units	MRV	EQS	2012	2013
2,4-Dibromophenol	$ng\ L^{-1}$	1.00	n/a	<1.0	<1.0
Bromophenol	$ng\ L^{-1}$	1.00	n/a	<1.0	<1.0
Monobromoacetic acid	$ng\ L^{-1}$	1.00	n/a	<1.0	<1.0
Dibromoacetic acid	$ng\ L^{-1}$	1.00	n/a	5.48	13.4
Bromochloroacetic acid	$ng\ L^{-1}$	1.00	n/a	2.47	4.7
Monochloroacetic acid	$ng\ L^{-1}$	1.00	n/a	6.08	12.1
Dichloroacetic acid	$ng\ L^{-1}$	1.00	n/a	<1.0	<1.0
Bromate	$ng\ L^{-1}$	1.00	n/a	<1.0	<1.0
2-Bromocyclohexanol	$ng\ L^{-1}$	1.00	n/a	<1.0	<1.0
1,2-Dibromocyclohexanol	$ng\ L^{-1}$	1.00	n/a	<1.0	<1.0
Total Organic Carbon (TOC)	$mg\ L^{-1}$	1.00	n/a	3.76	6.5

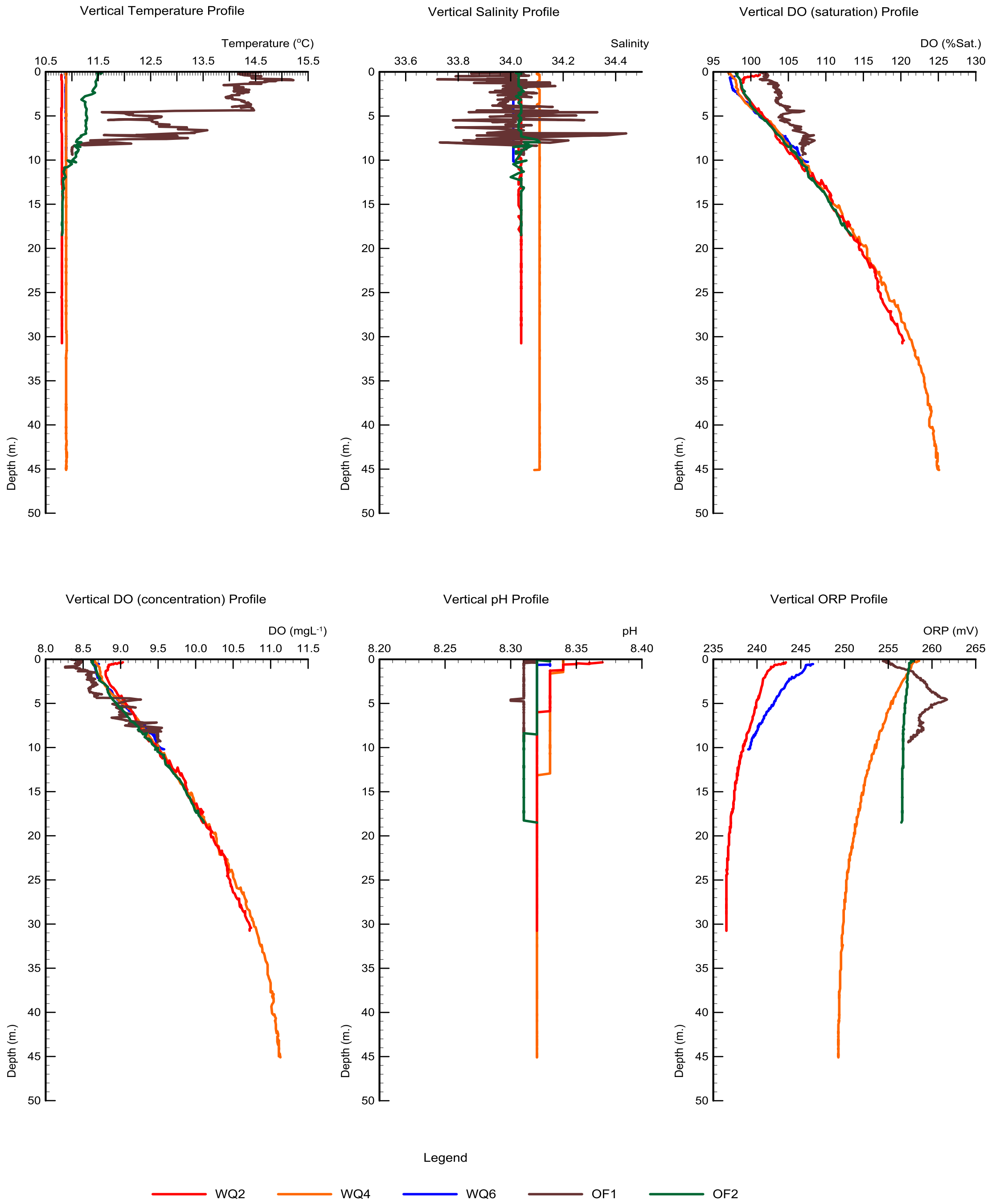
Appendix E. Water Quality – Vertical Profiles Recorded Before and After the Non-operational Conditions Started

Two sets of vertical profiles were produced per survey. The first set includes all sites included in previous year's monitoring programme (WQ2, WQ4, WQ6, WQ7, WQ8 and WQ9). The second set includes the water column vertical profiles recorded at the two additional sites (OF1 and OF2) as well as sites WQ2, WQ4 and WQ6. The three latter sites were included in the second set to add context to the profiles recorded at the additional sites (see Figure 4.1).

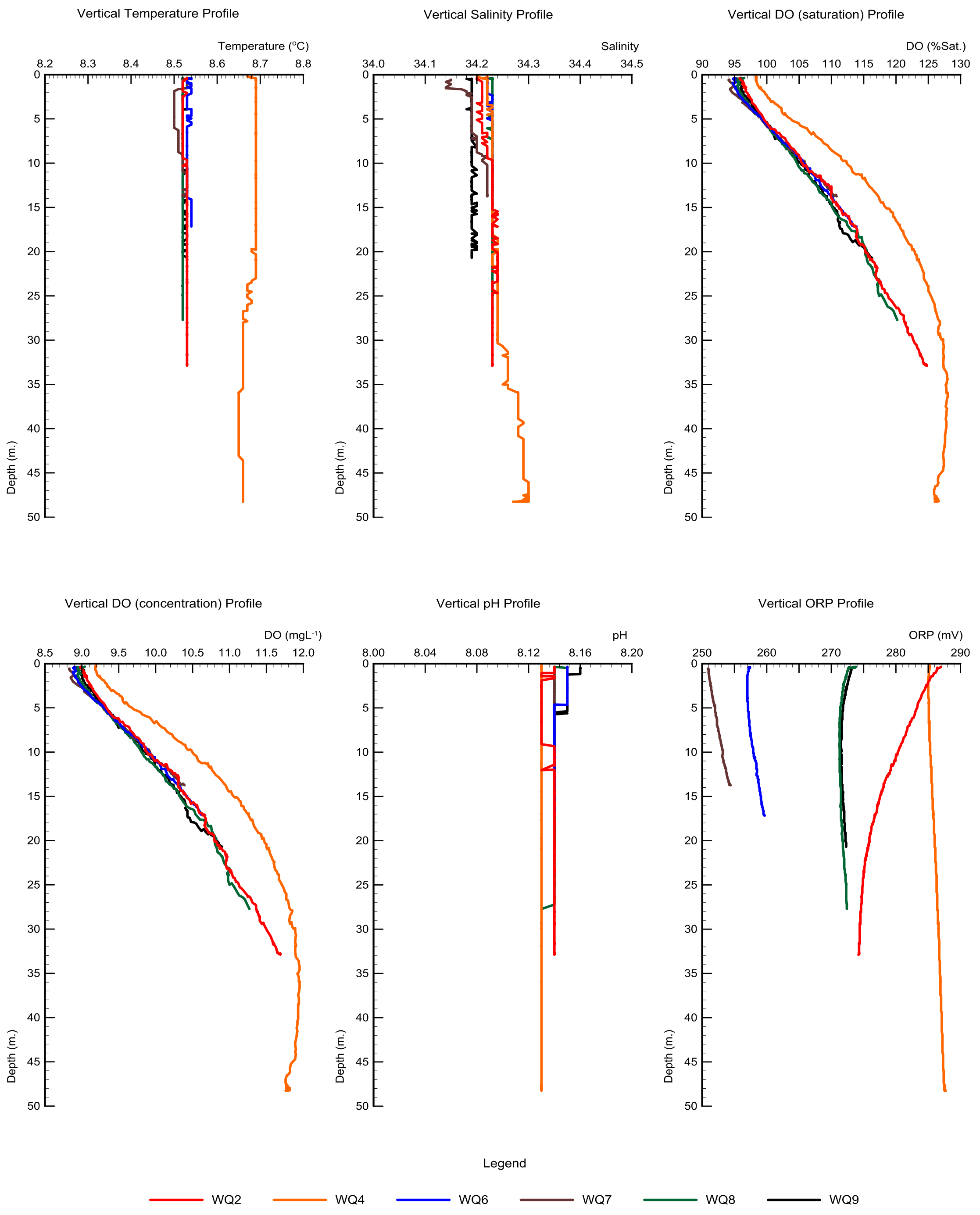
Vertical Water Column Profiles
December 2015



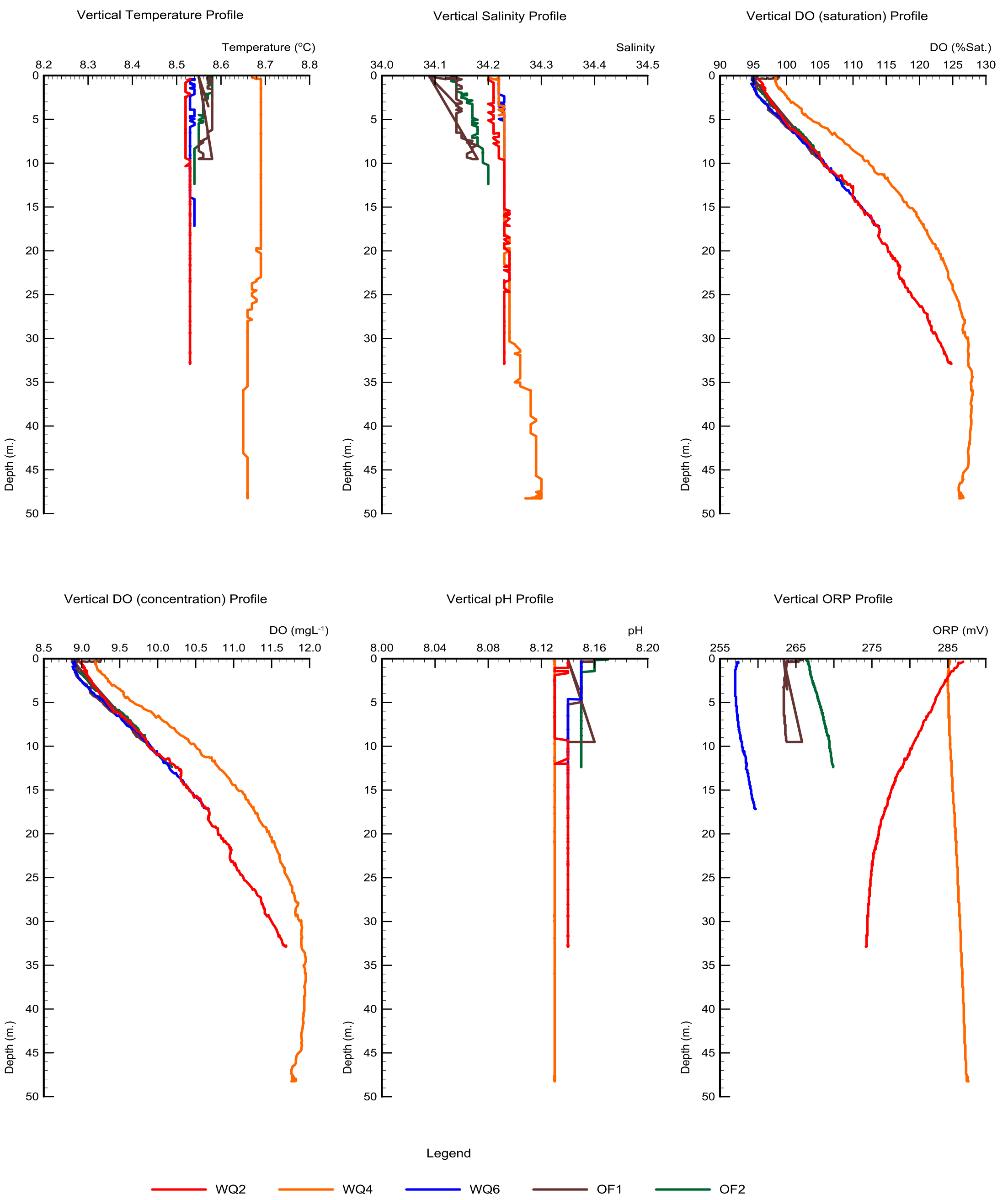
Vertical Water Column Profiles - Including Outfall Sites
December 2015



Vertical Water Column Profiles
February 2016



Vertical Water Column Profiles - Including Outfall Sites
February 2016



Appendix F. Water Quality – Laboratory Analysis Results Reported Before and After the Non-operational Conditions Started

Table F.1 : Physico-chemical properties. MRVs and mean values reported.

Compound	Units	MRV	Dec-15	Feb-16
Temperature of Water	Cel	n/a	10.79	8.57
pH	pH Units	0.05	8.31	8.14
Organic Carbon: Dissolved as C {DOC}	mg L^{-1}	0.2	0.55	0.70
Organic Carbon: Total as C {TOC}	mg L^{-1}	1	<1	<1
Suspended Solids at 105 °C	mg L^{-1}	3	16.35	16.63

Table F.2 : Cations and Anions concentrations. MRVs and mean values reported.

Compound	Units	MRV	Dec-15	Feb-16
Bromide	mg L^{-1}	0.05	65.9	66.9
Calcium, Dissolved	mg L^{-1}	10	419	405
Potassium, Dissolved	mg L^{-1}	1	404	412
Sodium, Dissolved	mg L^{-1}	20	10525	10525
Sulphate, Dissolved as SO_4	mg L^{-1}	5	2630	2578

Table F.3 : Nutrients concentrations. MRVs, EQSs and mean values reported.

Compound	Units	MRV	EQS	Dec-15	Feb-16
Orthophosphate as P (Filtered)	mg L^{-1}	0.01	n/a	0.036	0.018
Silicate as SiO_2 (Filtered)	mg L^{-1}	0.2	n/a	0.2975	0.355
Nitrate, Filtered as N (Filtered)	mg L^{-1}	0.1	n/a	<0.100	<0.100
Nitrite as N (Filtered)	mg L^{-1}	0.004	n/a	<0.00400	<0.00400
Nitrogen as N	mg L^{-1}	0.1	n/a	0.210	0.189

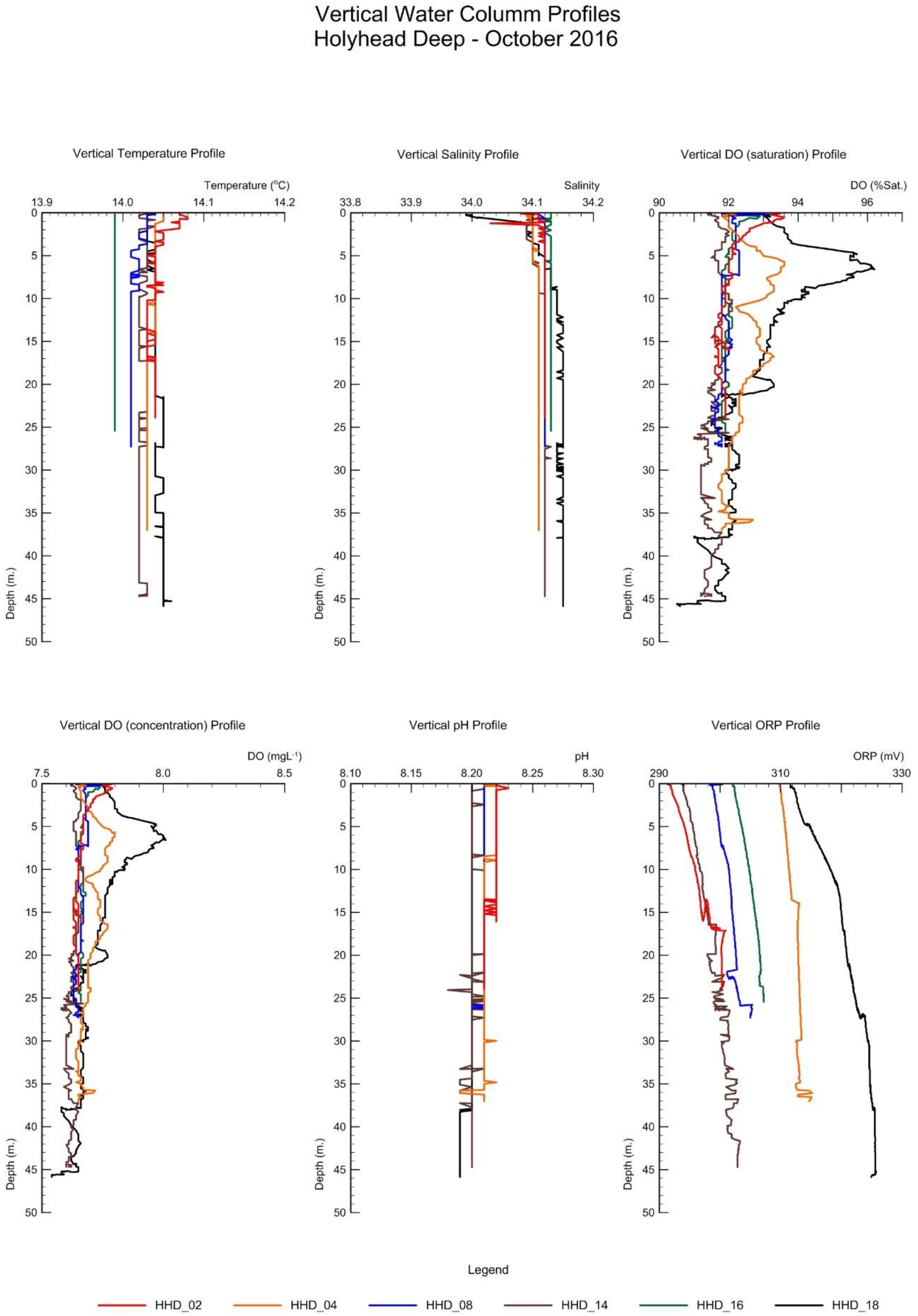
Compound	Units	MRV	EQS	Dec-15	Feb-16
Nitrogen, Total Oxidised as N (Filtered)	mg L^{-1}	0.1	n/a	<0.100	0.1025
Nitrogen, Total Organic as N	mg L^{-1}	n/a	n/a	<0.980	<0.980
Nitrogen, Inorganic, Filtered as N	mg L^{-1}	n/a	n/a	<0.120	<0.120
Nitrogen, Kjeldahl as N	mg L^{-1}	n/a	n/a	<1.00	<1.00
Ammoniacal Nitrogen as N (Filtered)	mg L^{-1}	0.02	n/a	<0.0200	<0.0200
Ammonia un-ionised as N	µg L^{-1}	n/a	21	<0.782	<0.448

Table F.4 : Metals concentrations. MRVs, EQSs and mean values reported.

Compound	Units	MRV	EQS	Dec-15	Feb-16
Arsenic, Dissolved	µg L^{-1}	1	25	1.73	1.53
Copper, Dissolved	µg L^{-1}	0.2	3.76	0.63	0.50
Lead, Dissolved	µg L^{-1}	0.04	1.3	0.07	0.05
Nickel, Dissolved	µg L^{-1}	0.3	8.6	0.44	<0.3
Zinc, Dissolved	µg L^{-1}	0.4	7.9	2.35	2.40
Boron, Dissolved	µg L^{-1}	700	7000	4088	4235
Mercury, Total	µg L^{-1}	0.01	0.07	<0.01	<0.01
Mercury, Dissolved	µg L^{-1}	0.01	0.07	<0.01	<0.01
Chromium, Dissolved	µg L^{-1}	0.5	15	<0.5	<0.5
Cadmium, Dissolved	µg L^{-1}	0.04	0.2	<0.03	<0.03
Selenium Dissolved	µg L^{-1}	1	n/a	<1	<1
Cobalt, Dissolved	µg L^{-1}	10	3*	<10	<10
Tin, Dissolved	µg L^{-1}	20	10*	<20	<20
Vanadium, Dissolved	µg L^{-1}	20	100	<20	<20
Manganese, Dissolved	µg L^{-1}	20	n/a	<20	<20
Iron, Dissolved	µg L^{-1}	100	1000	<100	<100

* These EQSs for List II substances have been initially proposed through research programmes run by Defra and other regulatory bodies (such as the Environment Agency), based on a critical assessment of all the available data. While they remain non-statutory, they are used by regulatory bodies.

Appendix G. Water Quality – Vertical Profiles Recorded at Holyhead Deep



Appendix H. Water Quality – Laboratory Analysis Results Reported at Holyhead Deep

Table H.1 : Physico-chemical results.

Compound	Units	MRV	Mean	HHD_02	HHD_02	HHD_04	HHD_04	HHD_08	HHD_08	HHD_14	HHD_14	HHD_16	HHD_16	HHD_18	HHD_18
Sampling Depth	m	n/a	n/a	1	33.4	1	29.5	1	31	1	36	1	30	1	34.5
Temperature of Water (*in situ*)	ºC	n/a	14.03	14.07	14.04	14.05	14.03	14.03	14.01	14.03	14.02	13.99	13.99	14.03	14.04
pH (*in situ*)	pH Units	0.05	8.21	8.22	8.21	8.22	8.21	8.21	8.21	8.20	8.20	8.21	8.20	8.20	8.20
DO% (*in situ*)	mg L^{-1}	5	92.1	93.3	91.9	92.0	92.0	92.1	91.8	91.6	91.3	92.3	91.9	93.2	92.2
BOD 5 Day ATU	mg L^{-1}	1	<1.00	<1.00	<1.00	<1.00	<1.00	1.15	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Organic Carbon: Dissolved as C {DOC}	mg L^{-1}	0.2	1.06	1.10	1.20	1.00	1.10	1.10	1.00	1.10	1.00	1.00	1.10	0.90	1.10
Organic Carbon: Total as C {TOC}	mg L^{-1}	1	0.81	0.80	0.86	0.79	0.84	0.77	0.86	0.80	0.81	0.78	0.84	0.77	0.79
Suspended Solids at 105 C	mg L^{-1}	3	5.53	<3.00	6.50	3.60	14.70	<3.00	3.90	4.90	5.60	5.20	9.30	4.90	4.70

Table H.2 : Anion and Cations concentrations.

Compound	*Units*	MRV	Mean	HHD_02	HHD_02	HHD_04	HHD_04	HHD_08	HHD_08	HHD_14	HHD_14	HHD_16	HHD_16	HHD_18	HHD_18
Sampling Depth	m	n/a	n/a	1	33.4	1	29.5	1	31	1	36	1	30	1	34.5
Bromide	mg L^{-1}	0.05	66.1	65.9	66.2	65.9	66.7	65.5	66.2	66.0	66.0	66.8	66.1	66.2	66.2
Calcium, Dissolved	mg L^{-1}	10	425.4	427	411	439	404	437	406	434	439	424	409	421	454
Potassium, Dissolved	mg L^{-1}	1	420.3	442	416	428	418	441	435	438	393	449	401	411	371
Sodium, Dissolved	mg L^{-1}	20	10284.2	10400	10200	10500	10300	10300	10700	10300	9770	10500	10200	10600	9640
Sulphate, Dissolved as SO4	mg L^{-1}	5	2578.3	2560	2620	2550	2680	2480	2770	2490	2510	2600	2590	2590	2500

Table H.3 : Nitrogen and Nutrients concentrations.

Compound (Dissolved)	Units	MRV	EQS	Mean	HHD_02	HHD_02	HHD_04	HHD_04	HHD_08	HHD_08	HHD_14	HHD_14	HHD_16	HHD_16	HHD_18	HHD_18
Sampling Depth	m	n/a		n/a	1	33.4	1	29.5	1	31	1	36	1	30	1	34.5
Nitrogen, as N	mg L^{-1}	0.1	n/a	0.183	0.165	0.166	0.179	0.180	0.182	0.190	0.171	0.213	0.186	0.205	0.182	0.182

Compound (Dissolved)	Units	MRV	EQS	Mean	HHD_02	HHD_02	HHD_04	HHD_04	HHD_08	HHD_08	HHD_14	HHD_14	HHD_16	HHD_16	HHD_18	HHD_18
Sampling Depth	m	n/a		n/a	1	33.4	1	29.5	1	31	1	36	1	30	1	34.5
Ammoniacal Nitrogen	mg L^{-1}	0.02	n/a	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Un-ionised Ammonia	µg L^{-1}	n/a	21	<0.785	<0.809	<0.790	<0.808	<0.789	<0.789	<0.788	<0.772	<0.771	<0.787	<0.770	<0.772	<0.772
Total Organic Nitrogen	mg L^{-1}	n/a	n/a	<0.980	<0.980	<0.980	<0.980	<0.980	<0.980	<0.980	<0.980	<0.980	<0.980	<0.980	<0.980	<0.980
Inorganic Nitrogen	mg L^{-1}	n/a	n/a	<0.120	<0.120	<0.120	<0.120	<0.120	<0.120	<0.120	<0.120	<0.120	<0.120	<0.120	<0.120	<0.120
Total Oxidised Nitrogen	mg L^{-1}	0.1	n/a	<0.004	<0.004	<<0.004	0.0056	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Kjeldahl Nitrogen	mg L^{-1}	n/a	n/a	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Nitrite	mg L^{-1}	0.004	n/a	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Nitrate	mg L^{-1}	0.1	n/a	<0.100	<0.100	<0.100	<0.0944	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100	<0.100
Orthophosphate, as P	mg L^{-1}	0.01	n/a	0.015	0.015	0.015	0.014	0.014	0.014	0.015	0.015	0.014	0.015	0.015	0.014	0.014
Silicate, as SiO_2	mg L^{-1}	0.2	n/a	<0.200	<0.200	<0.200	<0.200	<0.200	0.2	<0.200	0.2	0.2	<0.200	0.2	0.2	0.2
Chlorophyll (acetone extracted)	µg L^{-1}	0.01	n/a	0.721	0.590	0.790	0.630	0.650	0.600	0.690	0.750	0.850	0.720	0.760	0.950	0.670

Table H.4 : Dissolved metals concentrations.

Compound	*Units*	*MRV*	*EQS*	Mean	HHD_02	HHD_02	HHD_04	HHD_04	HHD_08	HHD_08	HHD_14	HHD_14	HHD_16	HHD_16	HHD_18	HHD_18
Sampling Depth	m	n/a		n/a	1	33.4	1	29.5	1	31	1	36	1	30	1	34.5
Arsenic, Dissolved	µg L^{-1}	1	25	1.50	1.52	1.40	1.38	1.58	1.35	1.53	1.48	1.48	1.55	1.57	1.50	1.62
Copper, Dissolved	µg L^{-1}	0.2	3.76	0.55	0.49	0.54	0.51	0.52	0.42	0.46	0.48	0.67	0.61	0.55	0.45	0.89
Lead, Dissolved	µg L^{-1}	0.04	1.3	0.91	0.29	1.52	0.28	0.70	0.11	0.87	0.15	3.40	0.27	1.42	0.11	1.80
Nickel, Dissolved	µg L^{-1}	0.3	8.6	<0.3	<0.3	0.31	<0.3	<0.3	<0.3	<0.3	<0.3	0.31	<0.3	0.35	<0.3	0.46
Zinc, Dissolved	µg L^{-1}	0.4	7.9	4.32	2.93	5.00	3.41	3.48	1.37	2.94	2.00	5.35	3.83	6.05	2.68	12.80
Boron, Dissolved	µg L^{-1}	700	7000	4483	4310	4390	4550	4360	4510	4450	4510	4730	4380	4390	4300	4920
Mercury, Total	µg L^{-1}	0.01	0.07	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mercury, Dissolved	µg L^{-1}	0.01	0.07	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium, Dissolved	µg L^{-1}	0.5	15	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5

Compound	Units	MRV	EQS	Mean	HHD_02	HHD_02	HHD_04	HHD_04	HHD_08	HHD_08	HHD_14	HHD_14	HHD_16	HHD_16	HHD_18	HHD_18
Sampling Depth	m	n/a		n/a	1	33.4	1	29.5	1	31	1	36	1	30	1	34.5
Cadmium, Dissolved	$\mu g\ L^{-1}$	0.04	0.2	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Selenium Dissolved	$\mu g\ L^{-1}$	1	n/a	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cobalt, Dissolved	$\mu g\ L^{-1}$	10	3*	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Tin, Dissolved	$\mu g\ L^{-1}$	20	10*	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Vanadium, Dissolved	$\mu g\ L^{-1}$	20	100	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Manganese, Dissolved	$\mu g\ L^{-1}$	20	n/a	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
Iron, Dissolved	$\mu g\ L^{-1}$	100	1000	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20

* These EQSs for List II substances have been initially proposed through research programmes run by Defra and other regulatory bodies (such as the Environment Agency), based on a critical assessment of all the available data. While they remain non-statutory, they are used by regulatory bodies.

Table H.5 : Organic compounds and cyanide concentrations

Compound	Units	MRV	EQS	Mean	HHD_02	HHD_02	HHD_04	HHD_04	HHD_08	HHD_08	HHD_14	HHD_14	HHD_16	HHD_16	HHD_18	HHD_18
Sampling Depth	m	n/a		n/a	1	33.4	1	29.5	1	31	1	36	1	30	1	34.5
Hydrocarbons Screen >C5 - C44	$mg\ L^{-1}$	0.2	n/a	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Di-2-ethylhexyl phthalate {DEHP}	$mg\ L^{-1}$	0.2	n/a	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Cyanide, Free as CN	$\mu g\ L^{-1}$	0.10	1	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cyanide as CN	$\mu g\ L^{-1}$	0.10	1	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500	<0.500

Appendix I. Water Quality – Physico-chemcials Parameters and Laboratory Analysis Results Reported at Cemlyn Lagoon

Table I.1 : Physico-chemical parameters.

Parameter (*in situ*)	Units	October 2017				November 2017				December 2017			
		ST1	ST2	ST3	ST4	ST1	ST2	ST3	ST4	ST1	ST2	ST3	ST4
Water Temperature	ºC	11.39	10.45	9.25	11.25	11.70	11.70	11.80	11.80	3.90	1.50	2.00	2.00
Salinity	Unitless	16.89	25.49	22.16	27.92	9.55	23.33	22.03	23.78	15.32	12.48	18.31	18.09
Conductivity	mS cm^{-1}	20.350	28.929	24.710	32.053	12.132	27.517	26.178	28.061	15.262	11.782	17.058	16.862
DO concentration	mg L^{-1}	8.31	7.97	10.07	8.57	10.32	9.68	9.49	9.26	13.32	13.76	12.57	13.08
DO saturation	%	84.6	83.9	101.0	93.3	101.0	103.3	100.6	99.3	112.4	106.9	103.1	107.1
pH	n/a	7.92	7.89	8.16	8.03	8.22	8.28	8.29	8.25	8.17	7.62	8.12	8.22

Table I.2 : BOD, organic carbon, total suspended solids and chlorophyll concentrations.

Compound	Units	MRV	October 2017				November 2017			
			ST1	ST2	ST3	ST4	ST1	ST2	ST3	ST4
BOD 5 Day ATU	mg L^{-1}	1	1.12	1.20	1.41	1.58	1.30	<1.00	1.47	<1.00
Organic Carbon: Dissolved as C {DOC}	mg L^{-1}	0.2	4.89	3.45	4.91	2.48	5.32	2.53	3.03	2.41
Organic Carbon: Total as C {TOC}	mg L^{-1}	0.7	4.60	3.80	4.70	2.50	5.10	2.80	3.70	2.70
Suspended Solids at 105°C	mg L^{-1}	3	8.20	6.70	5.70	17.10	18.70	5.40	4.20	3.00
Chlorophyll	µg L^{-1}	0.5	6.20	9.30	10.60	6.10	6.40	4.00	5.10	4.10

Table I.3 : Anions and cations concentrations.

Compound	*Units*	MRV	October 2017				November 2017			
			ST1	ST2	ST3	ST4	ST1	ST2	ST3	ST4
Bromate	mg L^{-1}	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bromide	mg L^{-1}	0.25	31.8	48.8	41.4	53.6	18.5	47.2	43.4	46.9
Calcium, Dissolved	mg L^{-1}	10	222	312	280	346	14	281	275	273
Potassium, Dissolved	mg L^{-1}	1	243	345	273	399	11	327	284	240
Sodium, Dissolved	mg L^{-1}	20	5200	7700	6750	8340	305	7150	6880	6790
Sulphate, Dissolved as SO4	mg L^{-1}	5	1350	2030	1760	2300	76	1860	1800	1740

Table I.4 : Nitrogen and nutrients concentrations.

Compound	*Units*	MRV	EQS	October 2017				November 2017			
				ST1	ST2	ST3	ST4	ST1	ST2	ST3	ST4
Nitrogen, as N	mg L^{-1}	0.1		1.690	0.689	0.910	0.633	2.510	0.760	0.848	0.703
Ammoniacal Nitrogen	mg L^{-1}	0.02		0.045	0.027	0.022	<0.020	0.062	0.031	0.030	0.025
Un-ionised Ammonia	µg L^{-1}	n/a	21	0.729	0.408	0.594	<0.403	2.110	1.200	1.200	0.915
Total Organic Nitrogen	mg L^{-1}	n/a		<0.955	<0.973	<0.978	<0.980	<0.938	<0.969	<0.970	<0.975
Inorganic Nitrogen	mg L^{-1}	n/a		1.250	0.277	0.412	<0.340	2.050	0.421	0.490	0.375
Total Oxidised Nitrogen	mg L^{-1}	0.1		1.20	0.25	0.39	0.32	1.99	0.39	0.46	0.35
Kjeldahl Nitrogen	mg L^{-1}	n/a		<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Nitrite	mg L^{-1}	0.004		0.014	0.009	0.011	0.010	0.026	0.010	0.010	0.009
Nitrate	mg L^{-1}	n/a		1.190	0.241	0.379	0.310	1.960	0.380	0.450	0.341
Orthophosphate, as P	mg L^{-1}	0.01		0.019	<0.0100	<0.010	0.015	0.023	0.010	<0.010	<0.010
Silicate, as SiO_2	mg L^{-1}	0.2		4.63	0.65	1.32	1.13	5.74	0.57	1.03	0.50

Table I.5 : Dissolved metals concentrations.

Compound	*Units*	MRV	EQS	October				November			
				ST1	ST2	ST3	ST4	ST1	ST2	ST3	ST4
Arsenic, Dissolved	$\mu g\ L^{-1}$	1	25	<1	<1	<1	1.130	<1	<1	<1	<1
Copper, Dissolved	$\mu g\ L^{-1}$	0.2	3.76	0.816	0.624	0.668	0.600	1.240	1.040	1.030	0.947
Lead, Dissolved	$\mu g\ L^{-1}$	0.04	1.3	<0.04	0.048	<0.04	0.044	0.062	0.058	0.081	0.059
Nickel, Dissolved	$\mu g\ L^{-1}$	0.3	8.6	0.904	0.792	0.846	0.607	0.826	0.600	0.538	0.518
Zinc, Dissolved	$\mu g\ L^{-1}$	0.4	7.9	3.28	2.37	2.59	1.82	2.06	2.26	3.04	1.86
Boron, Dissolved	$\mu g\ L^{-1}$	700	7000	2200	3350	2960	3780	<700	2970	2820	2870
Mercury, Total	$\mu g\ L^{-1}$	0.01	0.07	<0.01	<0.01	<0.01	<0.01	<0.01	0.016	<0.01	<0.01
Mercury, Dissolved	$\mu g\ L^{-1}$	0.01	0.07	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium, Dissolved	$\mu g\ L^{-1}$	0.5	15	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cadmium, Dissolved	$\mu g\ L^{-1}$	0.04	0.2	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Selenium Dissolved	$\mu g\ L^{-1}$	1		<1	<1	<1	<1	<1	<1	<1	<1
Cobalt, Dissolved	$\mu g\ L^{-1}$	10	3*	<10	<10	<10	<10	<10	<10	<10	<10
Tin, Dissolved	$\mu g\ L^{-1}$	20	10*	<20	<20	<20	<20	<20	<20	<20	<20
Vanadium, Dissolved	$\mu g\ L^{-1}$	20	100	<20	<20	<20	<20	<20	<20	<20	<20
Manganese, Dissolved	$\mu g\ L^{-1}$	20		87.70	35.70	23.00	42.90	26.80	33.20	<20	<20
Iron, Dissolved	$\mu g\ L^{-1}$	100	1000	<100	<100	<100	<100	<100	<100	<100	<100

* These EQSs for List II substances have been initially proposed through research programmes run by Defra and other regulatory bodies (such as the Environment Agency), based on a critical assessment of all the available data. While they remain non-statutory, they are used by regulatory bodies.

Table I.6 : Organic compounds reported above the laboratory MRV.

Compound	*Units*	MRV	EQS	October				November			
				ST1	ST2	ST3	ST4	ST1	ST2	ST3	ST4
Phenol	$\mu g\ L^{-1}$	0.05	7.7	0.104	0.132	0.307	0.157	0.165	0.096	0.196	0.081
4-Methylphenol (p-cresol)	$\mu g\ L^{-1}$	0.02		0.031	<0.02	<0.02	<0.02	0.030	<0.02	<0.02	<0.02
Di-2-ethylhexyl phthalate (DEHP)	$\mu g\ L^{-1}$	0.2	1.3	<0.2	<0.2	<0.2	<0.2	<0.2	0.282	<0.2	<0.2

Table I.7 : List of all other organic compounds analysed but reported as below MRV.

Organochlorine pesticides (OCPs)	Polychlorinated biphenyls (PCBs)	Polycyclic aromatic hydrocarbons (PAHs)	Phenols	Volatile organic compounds (VOCs)	
1,2,3-Trichlorobenzene	PCB - 008	Acenaphthene	2,3-Dichlorophenol	1,1,1,2-Tetrachloroethane	Bromoform {Tribromomethane}
1,2,4-Trichlorobenzene	PCB - 020	Acenaphthylene	2,3-Dimethylphenol	1,1,1-Trichloroethane	Carbon Disulphide
1,3,5-Trichlorobenzene	PCB - 028	Anthracene	2,4,5-Trichlorophenol	1,1,2,2-Tetrachloroethane	Carbon tetrachloride
2,3,5,6-Tetrachloroaniline	PCB - 031	Benzo(a)anthracene	2,4,6-Trichlorophenol	1,1,2-Trichloroethane	Chlorobenzene
2,3,5,6-Tetrachlorothioanisole	PCB - 035	Benzo(a)pyrene	2,4-Dichlorophenol	1,1-Dichloroethane	Chlorodibromomethane
Aldrin	PCB - 052	Benzo(b)fluoranthene	2,4-Dimethylphenol	1,1-Dichloroethylene	Chloroform {Trichloromethane}
Chlorothalonil	PCB - 077	Benzo(e)pyrene	2,5-Dichlorophenol	1,1-Dichloropropylene	Chloromethane
Chlorpropham	PCB - 101	Benzo(ghi)perylene	2,5-Dimethylphenol	1,2,3-Trichlorobenzene	Dibromomethane
DDE -op	PCB - 105	Benzo(k)fluoranthene	2,6-Dichlorophenol	1,2,3-Trichloropropane	Dichloromethan
DDE -pp	PCB - 118	Chrysene	2,6-Dimethylphenol	1,2,3-Trimethylbenzene	Dimethylbenzenes (sum)
DDT -op	PCB - 126	Dibenzo(ah)anthracene	2-Chlorophenol	1,2,4-Trichlorobenzene	Ethyl tert-butyl ether {ETBE}
DDT -pp	PCB - 128	Fluoranthene	2-Ethylphenol	1,2,4-Trimethylbenzene	Ethylbenzene
Dichlobenil	PCB - 138	Fluorene	2-Methylphenol	1,2-Dibromo-3-chloropropane	Hexachlorobutadiene
Dieldrin	PCB - 149	Indeno(1,2,3-cd) pyrene	3,4-Dimethylphenol	1,2-Dibromoethane	Hexachloroethane
Endosulfan A	PCB - 153	Naphthalene	3,5-Dimethylphenol	1,2-Dichlorobenzene	Isopropylbenzene
Endosulfan B	PCB - 156	Perylene	3-Chlorophenol	1,2-Dichloroethane	MTBE {Methyl tert-butyl ether}

Organochlorine pesticides (OCPs)	Polychlorinated biphenyls (PCBs)	Polycyclic aromatic hydrocarbons (PAHs)	Phenols	Volatile organic compounds (VOCs)	
Endrin	PCB - 169	Phenanthrene	3-Methylphenol	1,2-Dichloropropane	Naphthalene
HCH -alpha	PCB - 170	Pyrene	4-Chloro-2-methylphenol	1,2-Dimethylbenzene	Styrene
HCH -beta	PCB - 180		4-Chloro-3,5-dimethylphenol	1,3,5-Trichlorobenzene	Tetrachloroethylene
HCH -delta			4-Chloro-3-methylphenol	1,3,5-Trimethylbenzene	Toluene
HCH -epsilon			4-Chlorophenol	1,3-Dichlorobenzene	Trichloroethylene
HCH -gamma			Pentachlorophenol	1,3-Dichloropropane	Trichlorofluoromethane
Heptachlor				1,4-Dichlorobenzene	Vinyl Chloride
Hexachlorobenzene				2,2-Dichloropropane	cis-1,2-Dichloroethylene
Hexachlorobutadiene				2-Chlorotoluene	cis-1,3-Dichloropropylene
Isodrin				3-Chlorotoluene	n-ButylBenzene
Methoxychlor				4-Chlorotoluene	n-Propylbenzene
Pendimethalin				4-Isopropyltoluene	sec-Butylbenzene
Pentachlorobenzene				Benzene	tert-Amyl methyl ether {TAME}
Propachlor				Bromobenzene	tert-Butylbenzene
TDE - op				Bromochloromethane	trans-1,2-Dichloroethylene
TDE - pp				Bromodichloromethane	trans-1,3-Dichloropropylene
Tecnazene					
Tri-allate					
Trifluralin					
Vinclozolin					
cis-Chlordane					
cis-Heptachlor epoxide					
trans-Chlordane					
trans-Heptachlor epoxide					

Appendix J. Water Quality – Laboratory Analysis Results Reported in Coastal Areas around Wylfa Newydd DCO

Table J.1 : Mean BOD, organic carbon, total suspended solids and chlorophyll concentrations reported each month in all areas. The A.A. (annual average) represents the mean value reported between May and November 2017.

Compound	Units	MRV	A.A.	May	Jun	Jul	Aug	Sep	Oct	Nov
BOD 5 Day ATU	mg L^{-1}	1	<1.00	1.32	1.77	<1.00	<1.00	-	<1.00	<1.00
Organic Carbon: Dissolved as C {DOC}	mg L^{-1}	0.2	1.62	1.23	2.20	1.35	1.78	-	1.65	1.51
Organic Carbon: Total as C {TOC}	mg L^{-1}	1	1.69	1.54	2.64	1.83	1.05	-	1.56	1.49
Suspended Solids at 105 C	mg L^{-1}	3	11.01	9.44	10.47	6.12	19.50	-	11.20	9.34
Chlorophyll	µg L^{-1}	0.5	2.71	2.82	3.73	2.82	2.78		2.03	2.10

Table J.2 :Mean anions and cations concentrations reported in all areas. The A.A. (annual average) represents the mean value reported between May and November 2017.

Compound	*Units*	MRV	Mean	May	Jun	July	Aug	Sep	Oct	Nov
Bromate	mg L^{-1}	0.1	<0.100	<0.100	<0.100	<0.100	<0.100	-	<0.100	<0.100
Bromide	mg L^{-1}	0.25	59.00	62.76	55.59	61.53	54.83	-	59.47	59.81
Calcium, Dissolved	mg L^{-1}	10	368	375	360	393	369	-	377	331
Potassium, Dissolved	mg L^{-1}	1	383	386	350	393	382	-	410	380
Sodium, Dissolved	mg L^{-1}	20	9451	9944	9101	10070	9489	-	9649	8455
Sulphate, Dissolved as SO4	mg L^{-1}	5	2484	2610	2376	2670	2519	-	2520	2209

Table J.3 : Mean nitrogen and nutrients concentrations reported in all areas. The A.A. (annual average) represents the mean value reported between May and November 2017.

Compound (Dissolved)	Units	MRV	EQS	A.A.	May	Jun	July	Aug	Sep	Oct	Nov
Nitrogen, as N	mg L^{-1}	0.1		0.373	0.249	0.451	0.224	0.299	-	0.424	0.593
Ammoniacal Nitrogen	mg L^{-1}	0.02		<0.0200	0.0391	0.0387	<0.0200	<0.0200	-	<0.0200	<0.0200
Un-ionised Ammonia	µg L^{-1}	n/a	21	0.582	1.105	0.602	<0.474	0.781	-	<0.479	0.526

Compound (Dissolved)	Units	MRV	EQS	A.A.	May	Jun	July	Aug	Sep	Oct	Nov
Total Organic Nitrogen	mg L^{-1}	n/a		<0.786	<0.786	<0.964	<0.980	<0.980	-	<0.955	<0.938
Inorganic Nitrogen	mg L^{-1}	n/a		0.166	<0.120	0.228	<0.120	<0.120	-	0.232	0.354
Total Oxidised Nitrogen	mg L^{-1}	0.1		0.156	<0.100	0.191	<0.100	<0.100	-	0.233	0.360
Kjeldahl Nitrogen	mg L^{-1}	n/a		<1.00	<1.00	<1.00	<1.00	<1.00	-	<1.00	<1.00
Nitrite	mg L^{-1}	0.004		0.00531	0.00316	0.00733	<0.00400	<0.00400	-	0.00924	0.00811
Nitrate	mg L^{-1}	n/a		0.1517	<0.0899	0.1856	<0.100	<0.100	-	0.2266	0.3529
Orthophosphate, as P	mg L^{-1}	0.01		0.0123	<0.0100	0.0143	<0.0100	0.0107	-	0.0180	0.0206
Silicate, as SiO_2	mg L^{-1}	0.2		0.685	0.306	0.733	0.413	0.487	-	0.929	1.241

Table J.4 : Mean dissolved metals concentrations reported in all areas. The A.A. (annual average) represents the mean value reported between May and November 2017.

Compound	Units	MRV	EQS	A.A.	May	Jun	July	Aug	Sep	Oct	Nov
Arsenic, Dissolved	µg L^{-1}	1	25	1.27	1.40	1.26	1.01	1.39	-	1.27	1.31
Copper, Dissolved	µg L^{-1}	0.2	3.76	0.76	0.82	1.00	0.64	0.72	-	0.61	0.78
Lead, Dissolved	µg L^{-1}	0.04	1.3	<0.04	0.04	0.06	<0.04	0.05	-	<0.04	<0.04
Nickel, Dissolved	µg L^{-1}	0.3	8.6	0.45	0.49	0.74	<0.3	0.46	-	0.48	0.40
Zinc, Dissolved	µg L^{-1}	0.4	7.9	2.23	2.86	2.40	1.64	1.68	-	2.65	2.17
Boron, Dissolved	µg L^{-1}	700	7000	3932	3821	3866	4253	3947	-	4086	3619
Mercury, Total	µg L^{-1}	0.01	0.07	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01
Mercury, Dissolved	µg L^{-1}	0.01	0.07	<0.01	<0.01	<0.01	<0.01	<0.01	-	<0.01	<0.01
Chromium, Dissolved	µg L^{-1}	0.5	15	<0.5	<0.5	<0.5	<0.5	<0.5	-	<0.5	<0.5
Cadmium, Dissolved	µg L^{-1}	0.04	0.2	<0.03	<0.03	<0.03	<0.03	<0.03	-	<0.03	<0.03
Selenium Dissolved	µg L^{-1}	1	n/a	<1	<1	<1	<1	<1	-	<1	<1
Cobalt, Dissolved	µg L^{-1}	10	3*	<10	<10	<10	<10	<10	-	<10	<10
Tin, Dissolved	µg L^{-1}	20	10*	<20	<20	<20	<20	<20	-	<20	<20
Vanadium, Dissolved	µg L^{-1}	20	100	<20	<20	<20	<20	<20	-	<20	<20

Compound	Units	MRV	EQS	A.A.	May	Jun	July	Aug	Sep	Oct	Nov
Manganese, Dissolved	µg L^{-1}	20	n/a	<20	<20	<20	<20	<20	-	22.91	<20
Iron, Dissolved	µg L^{-1}	100	1000	<100	<100	<100	<100	<100	-	<100	<100

* These EQSs for List II substances have been initially proposed through research programmes run by Defra and other regulatory bodies (such as the Environment Agency), based on a critical assessment of all the available data. While they remain non-statutory, they are used by regulatory bodies.

Table J.5 : Organic compunds concentrations regularly reported above the MRV. The A.A. (annual average) represents the mean value reported between May and November 2017.

Phenol concentrations in µg L^{-1} (EQS=7.7 µg L^{-1})	A.A.	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17
Cemlyn Stream (CWQ1)	0.0928	0.0584	0.0794		0.0573		0.104	0.165
Cemlyn Bay (CWQ2)	0.0598	0.0883	0.0522	<0.05	<0.05		0.0989	0.0696
Cemlyn Bay (CWQ3)	0.1155	0.0645	0.125	0.159	0.0696		0.144	0.131
Porth-y-pistyll (CWQ4)	0.1812		0.161	0.217	0.243		0.132	0.153
Porth-y-pistyll (CWQ5)	0.0911	0.152	<0.05	0.105	<0.05		0.0799	0.16
Porth Wylfa (CWQ6)	0.0908	0.0749	0.131	0.0521	<0.05		0.152	0.11
Camaes (CWQ7)	0.0785	0.0976	<0.05	0.11	<0.05		0.135	
Bromoform (Tribromomethane) concentrations in µg L^{-1}	**A.A.**	**May-17**	**Jun-17**	**Jul-17**	**Aug-17**	**Sep-17**	**Oct-17**	**Nov-17**
Cemlyn Stream (CWQ1)	<0.1	<0.1	<0.1		<0.1		<0.1	<0.1
Cemlyn Bay (CWQ2)	<0.1	<0.1	<0.1	0.14	0.11		<0.1	<0.1
Cemlyn Bay (CWQ3)	<0.1	<0.1	0.23	<0.1	<0.1		<0.1	<0.1
Porth-y-pistyll (CWQ4)	0.18	0.18	<0.1	0.2	0.22		0.37	<0.1
Porth-y-pistyll (CWQ5)	<0.1	0.16	0.75	0.27	0.34		0.3	0.32
Porth Wylfa (CWQ6)	<0.1	0.12	0.25	<0.1	<0.1		<0.1	<0.1
Camaes (CWQ7)	<0.1	<0.1	<0.1	0.22	<0.1		<0.1	<0.1

Appendix K. Phytoplankton

Table K.1 : Systematic taxonomy of phytoplankton species identified at all sites between May 2010 and September 2014.

Group	Taxon	Genus	Family	Order	Class	Phylum
Centric diatom	*Actinocyclus* sp.	Actinocyclus	Hemidiscaceae	Coscinodiscales	Bacillariophyceae	Ochrophyta
Centric diatom	*Actinoptychus* sp.	Actinoptychus	Heliopeltaceae	Coscinodiscales	Bacillariophyceae	Ochrophyta
Naked Dinoflagellate	*Akashiwo sanguinea*	Akashiwo	Gymnodiniaceae	Gymnodiniales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Alexandrium* sp.	Alexandrium	Gonyaulacaceae	Gonyaulacales	Dinophyceae	Myzozoa
Naked Dinoflagellate	*Amphidinium crassum*	Amphidinium	Gymnodiniaceae	Gymnodiniales	Dinophyceae	Myzozoa
Naked Dinoflagellate	*Amphidinium* spp.	Amphidinium	Gymnodiniaceae	Gymnodiniales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Armoured dinoflagellate* sp.				Dinophyceae	Myzozoa
Pennate diatom	*Asterionellopsis glacialis*	Asterionellopsis	Fragilariaceae	Fragilariales	Bacillariophyceae	Ochrophyta
Centric diatom	*Asteromphalus sp.*	Asteromphalus	Asterolampraceae	Asterolamprales	Bacillariophyceae	Ochrophyta
Pennate diatom	*Asteroplanus karianus* (previously *Asterionellopsis kariana)*	Asteroplanus	Fragilariaceae	Fragilariales	Bacillariophyceae	Ochrophyta
Pennate diatom	*Asterionellopsis* spp.	Asterionellopsis	Fragilariaceae	Fragilariales	Bacillariophyceae	Ochrophyta
Pennate diatom	*Bacillaria paxillifera*	Bacillaria	Bacillariaceae	Bacillariales	Bacillariophyceae	Ochrophyta
Centric diatom	Centric diatom spp.				Bacillariophyceae	Ochrophyta
Centric diatom	*Cerataulina pelagica*	Cerataulina	Hemiaulaceae	Hemiaulales	Bacillariophyceae	Ochrophyta
Centric diatom	*Cerataulina* spp.	Cerataulina	Hemiaulaceae	Hemiaulales	Bacillariophyceae	Ochrophyta
Armoured dinoflagellate	*Neoceratium furca* (previously *Ceratium furca)*	Neoceratium	Ceratiaceae	Gonyaulacales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Neoceratium fusus* (previously *Ceratium fusus)*	Neoceratium	Ceratiaceae	Gonyaulacales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Neoceratium horridum* (previously *Ceratium horridum)*	Neoceratium	Ceratiaceae	Gonyaulacales	Dinophyceae	Myzozoa

Group	Taxon	Genus	Family	Order	Class	Phylum
Armoured dinoflagellate	*Neoceratium lineatum* (previously *Ceratium lineatum)*	Neoceratium	Ceratiaceae	Gonyaulacales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Neoceratium macroceros* (previously *Ceratium macroceros)*	Neoceratium	Ceratiaceae	Gonyaulacales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Neoceratium minutum* (previously *Ceratium minutum)*	Neoceratium	Ceratiaceae	Gonyaulacales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Neoceratium tripos* (previously *Ceratium tripos)*	Neoceratium	Ceratiaceae	Gonyaulacales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Ceratium* spp.	Ceratium	Ceratiaceae	Gonyaulacales	Dinophyceae	Myzozoa
Centric diatom	*Chaetoceros (Hyalochaete)* spp.	Chaetoceros	Chaetocerotaceae	Chaetocerotanae	Bacillariophyceae	Ochrophyta
Centric diatom	*Chaetoceros (Phaeoceros)* spp.	Chaetoceros	Chaetocerotaceae	Chaetocerotanae	Bacillariophyceae	Ochrophyta
Centric diatom	*Chaetoceros danicus*	Chaetoceros	Chaetocerotaceae	Chaetocerotanae	Bacillariophyceae	Ochrophyta
Ciliate	*Cilliate* sp.					Ciliophora
Coccolithophorid	*Coccolithophorid* sp.				Prymnesiophyceae	Haptophyta
Pennate diatom	*Corethron hystrix*	Corethron	Corethraceae	Corethrales	Bacillariophyceae	Ochrophyta
Centric diatom	*Coscinodiscus wailesii*	Coscinodiscus	Coscinodiscaceae	Coscinodiscales	Bacillariophyceae	Ochrophyta
Centric diatom	*Coscinodiscus* spp.	Coscinodiscus	Coscinodiscaceae	Coscinodiscales	Bacillariophyceae	Ochrophyta
Cryptophyta	Cryptophytes				Cryptophyceae	Cryptophyta
Cyanobacteria	Cyanophytes				Cyanophyceae	Cyanobacteria
Pennate diatom	*Ceratoneis closterium* (previously *Cylindrotheca closterium)/Nitzschia longissima*	Ceratoneis	Fragilariaceae	Fragilariales	Bacillariophyceae	Ochrophyta
Centric diatom	*Dactyliosolen fragilissimus*	Dactyliosolen	Rhizosoleniaceae	Rhizosoleniales	Bacillariophyceae	Ochrophyta

Group	Taxon	Genus	Family	Order	Class	Phylum
Dictyochophyte	*Dictyocha fibula*	Dictyocha	Dictyochaceae	Dictyochales	Dictyochophyceae	Ochrophyta
Dictyochophyte	*Dictyocha speculum*	Dictyocha	Dictyochaceae	Dictyochales	Dictyochophyceae	Ochrophyta
Chrysophyte	*Dinobryon* spp.	Dinobryon	Dinobryaceae	Chromulinales	Chrysophyceae	Ochrophyta
Dinoflagellate cyst smooth	Dinoflagellate cysts (smooth)				Dinophyceae	Myzozoa
Dinoflagellate cyst spiny	Dinoflagellate cysts (spiny)				Dinophyceae	Myzozoa
Armoured dinoflagellate	*Dinophysis acuminata*	Dinophysis	Dinophysiaceae	Dinophysiales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Dinophysis* sp.	Dinophysis	Dinophysiaceae	Dinophysiales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Dinophysis acuta*	Dinophysis	Dinophysiaceae	Dinophysiales	Dinophyceae	Myzozoa
Pennate diatom	*Diploneis* sp.	Diploneis	Diploneidaceae	Naviculales	Bacillariophyceae	Ochrophyta
Armoured dinoflagellate	*Diplopsalis lenticula*	Diplopsalis	Protoperidiniaceae	Peridiniales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Diplopsalis* spp.	Diplopsalis	Protoperidiniaceae	Peridiniales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Diplopsalopsis bomba* (previously *Dissodium assymetricum)*	Diplopsalopsis	Protoperidiniaceae	Peridiniales	Dinophyceae	Myzozoa
Parasitic dinoflagellate	*Pyrocystis spp.* (previously *Dissodinium* spp.)	Pyrocystis	Pyrocystaceae	Pyrocystales	Dinophyceae	Myzozoa
Centric diatom	*Ditylum brightwellii*	Ditylum	Lithodesmiaceae	Lithodesmiales	Bacillariophyceae	Ochrophyta
Centric diatom	*Eucampia* spp.	Eucampia	Hemiaulaceae	Hemiaulales	Bacillariophyceae	Ochrophyta
Centric diatom	*Eucampia zodiacus*	Eucampia	Hemiaulaceae	Hemiaulales	Bacillariophyceae	Ochrophyta
Protist	*Euglena/Eutreptiella* spp.	Euglena/ Eutreptiella	Euglenaceae	Euglenida	Euglenoidea	Euglenozoa
Pennate diatom	*Fragilaria islandica*	Fragilaria	Fragilariaceae	Fragilariales	Bacillariophyceae	Ochrophyta
Pennate diatom	*Fragilariopsis* spp.	Fragilariopsis	Bacillariaceae	Bacillariales	Bacillariophyceae	Ochrophyta
Pennate diatom	*Fragilaria* spp.	Fragilaria	Fragilariaceae	Fragilariales	Bacillariophyceae	Ochrophyta
Armoured dinoflagellate	*Kryptoperidinium foliaceum* (previously *Glenodinium foliaceum)*	Kryptoperidinium	Peridiniaceae	Peridiniales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Glenodinium* spp.	Glenodinium	Peridiniaceae	Peridiniales	Dinophyceae	Myzozoa

Group	Taxon	Genus	Family	Order	Class	Phylum
Armoured dinoflagellate	*Gonyaulax* spp.	Gonyaulax	Gonyaulacaceae	Gonyaulacales	Dinophyceae	Myzozoa
Pennate diatom	*Grammatophora marina*	Grammatophora	Striatellaceae	Striatellales	Bacillariophyceae	Ochrophyta
Centric diatom	*Guinardia delicatula*	Guinardia	Rhizosoleniaceae	Rhizosoleniales	Bacillariophyceae	Ochrophyta
Centric diatom	*Guinardia flaccida*	Guinardia	Rhizosoleniaceae	Rhizosoleniales	Bacillariophyceae	Ochrophyta
Centric diatom	*Guinardia striata*	Guinardia	Rhizosoleniaceae	Rhizosoleniales	Bacillariophyceae	Ochrophyta
Naked Dinoflagellate	*Gymnodinium gracile*	Gymnodinium	Gymnodiniaceae	Gymnodiniales	Dinophyceae	Myzozoa
Naked Dinoflagellate	*Gymnodinium simplex*	Gymnodinium	Gymnodiniaceae	Gymnodiniales	Dinophyceae	Myzozoa
Naked Dinoflagellate	*Gymnodinium* spp.	Gymnodinium	Gymnodiniaceae	Gymnodiniales	Dinophyceae	Myzozoa
Naked Dinoflagellate	*Gyrodinium spirale*	Gyrodinium	Gymnodiniaceae	Gymnodiniales	Dinophyceae	Myzozoa
Naked Dinoflagellate	*Gyrodinium* spp.	Gyrodinium	Gymnodiniaceae	Gymnodiniales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Heterocapsa* spp.	Heterocapsa	Peridiniida incertae sedis	Peridiniales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Heterocapsa triquetra*	Heterocapsa	Peridiniida incertae sedis	Peridiniales	Dinophyceae	Myzozoa
Naked Dinoflagellate	*Karenia mikimotoi*	Karenia	Kareniaceae	Gymnodiniales	Dinophyceae	Myzozoa
Naked Dinoflagellate	*Katodinium* spp.	Katodinium	Gymnodiniaceae	Gymnodiniales	Dinophyceae	Myzozoa
Centric diatom	*Lauderia/Detonula* sp.	Lauderia	Lauderiaceae	Thalassiosirales	Bacillariophyceae	Ochrophyta
Pennate diatom	*Leptocylindrus danicus*	Leptocylindrus	Leptocylindraceae	Leptocylindrales	Bacillariophyceae	Ochrophyta
Pennate diatom	*Leptocylindrus mediterraneus*	Leptocylindrus	Leptocylindraceae	Leptocylindrales	Bacillariophyceae	Ochrophyta
Pennate diatom	*Leptocylindrus minimus*	Leptocylindrus	Leptocylindraceae	Leptocylindrales	Bacillariophyceae	Ochrophyta
Pennate diatom	*Licmophora* spp.	Licmophora	Licmophoraceae	Licmophorales	Bacillariophyceae	Ochrophyta
Centric diatom	*Melosira moniliformis*	Melosira	Melosiraceae	Melosirales	Bacillariophyceae	Ochrophyta
Centric diatom	*Melosira nummuloides*	Melosira	Melosiraceae	Melosirales	Bacillariophyceae	Ochrophyta
Centric diatom	*Melosira* spp.	Melosira	Melosiraceae	Melosirales	Bacillariophyceae	Ochrophyta
Ciliate	*Mesodinium rubrum*	Mesodinium	Mesodiniidae	Cyclotrichiida	Litostomatea	Ciliophora
Pennate diatom	*Meuniera membranacea*	Meuniera	Naviculaceae	Naviculales	Bacillariophyceae	Ochrophyta
Protist	*Microflagellate* sp.					

Group	Taxon	Genus	Family	Order	Class	Phylum
Armoured dinoflagellate	*Minuscula bipes*	Minuscula	Protoperidiniaceae	Peridiniales	Dinophyceae	Myzozoa
Chlorophyte	*Monoraphidium* spp.	Monoraphidium	Selenastraceae	Sphaeropleales	Chlorophyceae	Chlorophyta
Naked Dinoflagellate	*Naked Dinoflagellate* sp.				Dinophyceae	Myzozoa
Pennate diatom	*Navicula* spp.	Navicula	Naviculaceae	Naviculales	Bacillariophyceae	Ochrophyta
Naked Dinoflagellate	*Nematodinium* spp.	Nematodinium	Warnowiaceae	Gymnodiniales	Dinophyceae	Myzozoa
Centric diatom	*Neocalyptrella robusta*	Neocalyptrella	Rhizosoleniaceae	Rhizosoleniales	Bacillariophyceae	Ochrophyta
Naked Dinoflagellate	*Noctiluca scintillans*	Noctiluca	Noctilucaceae	Noctilucales	Dinophyceae	Myzozoa
Centric diatom	*Odontella mobiliensis*	Odontella	Triceratiaceae	Triceratiales	Bacillariophyceae	Ochrophyta
Centric diatom	*Odontella sinensis*	Odontella	Triceratiaceae	Triceratiales	Bacillariophyceae	Ochrophyta
Centric diatom	*Odontella* spp.	Odontella	Triceratiaceae	Triceratiales	Bacillariophyceae	Ochrophyta
Naked Dinoflagellate	*Oxyrrhis* sp.	Oxyrrhis	Oxyrrhinaceae	Oxyrrhinales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Oxytoxum* sp.	Oxytoxum	Oxytoxaceae	Peridiniales	Dinophyceae	Myzozoa
Centric diatom	*Paralia* sp.	Paralia	Paraliaceae	Paraliales	Bacillariophyceae	Ochrophyta
Centric diatom	*Paralia sulcata*	Paralia	Paraliaceae	Paraliales	Bacillariophyceae	Ochrophyta
Pennate diatom	Pennate diatom sp.			Bacillariales	Bacillariophyceae	Ochrophyta
Armoured dinoflagellate	*Peridinium* spp.	Peridinium	Peridiniaceae	Peridiniales	Dinophyceae	Myzozoa
Prymnesiophyte/ Haptophyte	*Phaeocystis globosa*	Phaeocystis	Phaeocystaceae	Phaeocystales	Prymnesiophyceae	Haptophyta
Armoured dinoflagellate	*Phalacroma rotundatum*	Phalacroma	Dinophysiaceae	Dinophysiales	Dinophyceae	Myzozoa
Pennate diatom	*Plagiogramma brockmanii*	Plagiogramma	Plagiogrammaceae	Triceratiales	Bacillariophyceae	Ochrophyta
Pennate diatom	*Plagiogrammopsis* sp.	Plagiogrammopsis	Cymatosiraceae	Cymatosirales	Bacillariophyceae	Ochrophyta
Pennate diatom	*Pleurosigma/Gyrosigma* sp.	Pleurosigma	Pleurosigmataceae	Naviculales	Bacillariophyceae	Ochrophyta
Armoured dinoflagellate	*Podolampas palmipes*	Podolampas	Podolampadaceae	Peridiniales	Dinophyceae	Myzozoa
Naked Dinoflagellate	*Polykrikos* spp.	Polykrikos	Polykrikaceae	Gymnodiniales	Dinophyceae	Myzozoa
Naked Dinoflagellate	*Polykrikos schwarzii*	Polykrikos	Polykrikaceae	Gymnodiniales	Dinophyceae	Myzozoa

Group	Taxon	Genus	Family	Order	Class	Phylum
Prasinophyte	*Prasinophytes*				Prasinophyceae	Chlorophyta
Centric diatom	*Proboscia alata*	Proboscia	Rhizosoleniaceae	Rhizosoleniales	Bacillariophyceae	Ochrophyta
Armoured dinoflagellate	*Prorocentrum balticum/minimum*	Prorocentrum	Prorocentraceae	Prorocentrales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Prorocentrum gracile*	Prorocentrum	Prorocentraceae	Prorocentrales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Prorocentrum lima*	Prorocentrum	Prorocentraceae	Prorocentrales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Prorocentrum micans*	Prorocentrum	Prorocentraceae	Prorocentrales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Prorocentrum* spp.	Prorocentrum	Prorocentraceae	Prorocentrales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Protoperidinium brevipes*	Protoperidinium	Protoperidiniaceae	Peridiniales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Protoperidinium excentricum*	Protoperidinium	Protoperidiniaceae	Peridiniales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Protoperidinium mite*	Protoperidinium	Protoperidiniaceae	Peridiniales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Protoperidinium pellucidum*	Protoperidinium	Protoperidiniaceae	Peridiniales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Protoperidinium pyriforme*	Protoperidinium	Protoperidiniaceae	Peridiniales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Protoperidinium* spp.	Protoperidinium	Protoperidiniaceae	Peridiniales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Protoperidinium steinii*	Protoperidinium	Protoperidiniaceae	Peridiniales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Protoperidinium crassipes*	Protoperidinium	Protoperidiniaceae	Peridiniales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Protoperidium diabolum*	Protoperidinium	Protoperidiniaceae	Peridiniida	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Protoperidium divergens*	Protoperidinium	Protoperidiniaceae	Peridiniida	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Protoperidium leonis*	Protoperidinium	Protoperidiniaceae	Peridiniida	Dinophyceae	Myzozoa
Prymnesiophyte/ Haptophyte	Prymnesiophytes				Prymnesiophyceae	Haptophyta
Pennate diatom	*Pseudo-nitzschia delicatissima* complex	Pseudo-nitzschia	Bacillariaceae	Bacillariales	Bacillariophyceae	Ochrophyta
Pennate diatom	*Pseudo-nitzschia seriata* complex	Pseudo-nitzschia	Bacillariaceae	Bacillariales	Bacillariophyceae	Ochrophyta
Raphidophytes	*Rhaphidophytes*				Raphidophyceae	Ochrophyta

Group	Taxon	Genus	Family	Order	Class	Phylum
Centric diatom	*Dactyliosolen fragilissimus*	Dactyliosolen	Rhizosoleniaceae	Rhizosoleniales	Bacillariophyceae	Ochrophyta
Centric diatom	*Rhizosolenia hebetata*	Rhizosolenia	Rhizosoleniaceae	Rhizosoleniales	Bacillariophyceae	Ochrophyta
Centric diatom	*Rhizosolenia imbricata*	Rhizosolenia	Rhizosoleniaceae	Rhizosoleniales	Bacillariophyceae	Ochrophyta
Centric diatom	*Rhizosolenia setigera*	Rhizosolenia	Rhizosoleniaceae	Rhizosoleniales	Bacillariophyceae	Ochrophyta
Centric diatom	*Rhizosolenia* spp.	Rhizosolenia	Rhizosoleniaceae	Rhizosoleniales	Bacillariophyceae	Ochrophyta
Centric diatom	*Rhizosolenia styliformis*	Rhizosolenia	Rhizosoleniaceae	Rhizosoleniales	Bacillariophyceae	Ochrophyta
Armoured dinoflagellate	*Scrippsiella* spp.	Scrippsiella	Peridiniaceae	Peridiniales	Dinophyceae	Myzozoa
Armoured dinoflagellate	*Scrippsiella trochoidea*	Scrippsiella	Peridiniaceae	Peridiniales	Dinophyceae	Myzozoa
Centric diatom	*Skeletonema costatum*	Skeletonema	Skeletonemaceae	Thalassiosirales	Bacillariophyceae	Ochrophyta
Centric diatom	*Skeletonema* spp.	Skeletonema	Skeletonemaceae	Thalassiosirales	Bacillariophyceae	Ochrophyta
Centric diatom	*Stephanopyxis turris*	Stephanopyxis	Stephanopyxidaceae	Melosirales	Bacillariophyceae	Ochrophyta
Pennate diatom	*Striatella* spp.	Striatella	Striatellaceae	Striatellales	Bacillariophyceae	Ochrophyta
Pennate diatom	*Striatella unuipunctata*	Striatella	Striatellaceae	Striatellales	Bacillariophyceae	Ochrophyta
Pennate diatom	*Thalassionema nitzschioides*	Thalassionema	Thalassionemataceae	Thalassionematales	Bacillariophyceae	Ochrophyta
Pennate diatom	*Thalassionema* sp.	Thalassionema	Thalassionemataceae	Thalassionematales	Bacillariophyceae	Ochrophyta
Centric diatom	*Thalassiosira anguste-lineata*	Thalassiosira	Thalassiosiraceae	Thalassiosirales	Bacillariophyceae	Ochrophyta
Centric diatom	*Thalassiosira rotula /gravida*	Thalassiosira	Thalassiosiraceae	Thalassiosirales	Bacillariophyceae	Ochrophyta
Centric diatom	*Thalassiosira* spp.	Thalassiosira	Thalassiosiraceae	Thalassiosirales	Bacillariophyceae	Ochrophyta
Tintinnid	Tintinnids			Tintinnida	Spirotrichea	Ciliophora
Naked Dinoflagellate	*Torodinium robustum*	Torodinium	Gymnodiniaceae	Gymnodiniales	Dinophyceae	Myzozoa
Chlorophyte	*Trachelomonas* sp.	Trachelomonas	Euglenaceae	Euglenida	Euglenoidea	Euglenozoa
Centric diatom	*Trigonium alternans*	Trigonium	Biddulphiaceae	Biddulphiales	Bacillariophyceae	Ochrophyta

Table K.2 : Output of two-way SIMPER analysis displaying contribution of phytoplankton taxa to 50% of the dissimilarity between seasons across all years.

Groups Spring & Summer	Average dissimilarity = 70.25					
	Group Spring	Group Summer				
Species	Average Abundance (square root)	Average Abundance (square root)	Average Dissimilarity	Dissimilarity/Standard Deviation	Contribution (%)	Cumulative (%
Guinardia delicatula	55.48	24.72	8.14	1.06	11.59	11.59
Guinardia flaccida	47.75	17.46	4.89	1.15	6.97	18.56
Leptocylindrus minimus	11.12	23.22	2.75	1.23	3.92	22.47
Leptocylindrus danicus	10.54	22.63	2.7	1.23	3.84	26.32
Skeletonema spp.	15.03	18.07	2.29	0.96	3.26	29.58
Paralia sulcata	4.22	17.41	2.14	1.01	3.05	32.63
Rhizosolenia spp.	8.15	20.2	2.09	0.63	2.97	35.59
Chaetocerus (Halochaete) spp.	7.34	15.28	1.99	1.06	2.84	38.43
Paralia sp.	26.95	12.97	1.66	0.78	2.36	40.79
Guinardia striata	6.26	10.31	1.55	0.85	2.2	43
Pseudo-nitzschia seriata complex	9.34	9.89	1.47	1.12	2.09	45.08
Thalassiosira rotula/gravida	8.47	2.78	1.37	0.71	1.95	47.04
Thalassionema nitzschioides	5.89	8.69	1.37	0.88	1.95	48.99
Pennate diatom sp.	12.32	17.75	1.32	1.16	1.89	50.88
Groups Spring & Autumn	**Average dissimilarity = 76.77**					
	Group Spring	**Group Autumn**				
Species	**Average Abundance (square root)**	**Average Abundance (square root)**	**Average Dissimilarity**	**Dissimilarity/Standard Deviation**	**Contribution (%)**	**Cumulative (%)**
Guinardia delicatula	55.48	7.71	10	1.03	13.03	13.03

Guinardia flaccida	47.75	2.93	5.93	1.1	7.73	20.76
Paralia sp.	26.95	20.49	3.88	0.87	5.05	25.81
Paralia sulcata	4.22	22.35	3.46	0.98	4.51	30.32
Leptocylindrus danicus	10.54	9.89	2.33	1.04	3.03	33.35
Pennate diatom sp.	12.32	17.09	2.19	1.36	2.85	36.21
Lauderia/Detonula sp.	24.06	7.26	1.82	0.9	2.38	38.58
Phaeocystis globosa	5.39	0.09	1.8	0.4	2.34	40.92
Skeletonema spp.	15.03	4.88	1.79	0.75	2.33	43.26
Leptocylindrus minimus	11.12	8.01	1.77	1.01	2.3	45.56
Thalassiosira rotula/gravida	8.47	1.66	1.75	0.7	2.28	47.85
Pseudo-nitzschia seriata complex	9.34	7.29	1.67	1.08	2.18	50.02
Groups Summer & Autumn	**Average dissimilarity = 71.86**					
	Group Summer	**Group Autumn**				
Species	**Average Abundance (square root)**	**Average Abundance (square root)**	**Average Dissimilarity**	**Dissimilarity/Standard Deviation**	**Contribution (%)**	**Cumulative (%)**
Paralia sulcata	17.41	22.35	3.96	1.19	5.52	5.52
Rhizosolenia spp.	20.2	2.8	3.89	0.63	5.41	10.93
Paralia sp.	12.97	20.49	3.82	0.82	5.31	16.24
Skeletonema spp.	18.07	4.88	3.38	0.94	4.7	20.94
Leptocylindrus danicus	22.63	9.89	3.13	1.21	4.36	25.29
Leptocylindrus minimus	23.22	8.01	3.05	1.22	4.24	29.54
Guinardia flaccida	17.46	2.93	3	0.78	4.18	33.71
Chaetoceros (Hyalochaete) spp.	15.28	6.09	2.15	0.96	2.98	36.7
Guinardia delicatula	24.72	7.71	2.13	0.76	2.97	39.67

Pennate diatom sp.	17.75	17.09	1.73	1.19	2.41	42.07
Pseudo-nitzschia seriata complex	9.89	7.29	1.69	1.11	2.36	44.43
Thalassionema nitzschioides	8.69	6.41	1.57	0.96	2.18	46.61
Thalassionema sp.	7.93	5.96	1.52	0.71	2.12	48.73
Centric diatom spp.	15.73	16.21	1.52	1.2	2.12	50.84
Groups Spring & Winter	**Average dissimilarity = 81.17**					
	Group Spring	**Group Winter**				
Species	**Average Abundance (square root)**	**Average Abundance (square root)**	**Average Dissimilarity**	**Dissimilarity/Standard Deviation**	**Contribution (%)**	**Cumulative (%)**
Guinardia delicatula	55.48	0	12.1	1.15	14.91	14.91
Guinardia flaccida	47.75	0.96	8.15	1.27	10.05	24.96
Paralia sulcata	4.22	29.75	4.48	1.31	5.52	30.48
Lauderia/Detonula sp.	24.06	5.05	3.71	1.02	4.57	35.04
Paralia sp.	26.95	13.32	3.5	0.95	4.31	39.36
Bacillaria paxillifera	15.06	12.92	2.44	0.91	3	42.36
Skeletonema spp.	15.03	3.04	2.31	0.67	2.84	45.2
Ceratoneis closterium /Nitzschia longissima	22.96	10.1	2.1	0.78	2.59	47.8
Thalassiosira spp.	7.27	5.58	1.88	0.77	2.31	50.11
Groups Summer & Winter	**Average dissimilarity = 77.62**					
	Group Summer	**Group Winter**				
Species	**Average Abundance (square root)**	**Average Abundance (square root)**	**Average Dissimilarity**	**Dissimilarity/Standard Deviation**	**Contribution (%)**	**Cumulative (%)**
Guinardia flaccida	17.46	0.96	4.44	0.83	5.73	5.73
Leptocylindrus minimus	23.22	3.54	4.28	1.46	5.51	11.24

Guinardia delicatula	24.72	0	3.9	1.58	5.02	16.26
Paralia sulcata	17.41	29.75	3.89	1.23	5.01	21.27
Leptocylindrus danicus	22.63	1.69	3.51	1.24	4.52	25.79
Chaetocerus (Halochaete) spp.	15.28	2.04	3.2	1.23	4.12	29.91
Paralia sp.	12.97	13.32	2.86	0.74	3.68	33.59
Guinardia striata	10.31	0.68	2.66	0.98	3.43	37.02
Skeletonema spp.	18.07	3.04	2.6	0.99	3.35	40.37
Rhizosolenia spp.	20.2	1.97	2.58	1.5	3.33	43.7
Pennate diatom sp.	17.75	8.56	2.01	1.32	2.58	46.28
Bacillaria paxillifera	2.84	12.92	1.85	0.83	2.38	48.67
Thalassiosira spp.	4.48	5.58	1.78	0.99	2.29	50.96
Groups Autumn & Winter	**Average dissimilarity = 71.31**					
	Group Autumn	**Group Winter**				
Species	**Average Abundance (square root)**	**Average Abundance (square root)**	**Average Dissimilarity**	**Dissimilarity/Standard Deviation**	**Contribution (%)**	**Cumulative (%)**
Paralia sp.	20.49	13.32	6.95	1.1	9.75	9.75
Paralia sulcata	22.35	29.75	5.96	1.28	8.36	18.11
Pennate diatom sp.	17.09	8.56	3.8	1.71	5.33	23.44
Bacillaria paxillifera	3.45	12.92	2.6	0.94	3.64	27.08
Thalassionema sp	5.96	3.19	2.52	1.01	3.54	30.62
Ceratoneis closterium/Nitzschia longissima	11.55	10.1	2.33	1.33	3.27	33.89
Guinardia delicatula	7.71	0	2.26	0.73	3.17	37.06
Skeletonema spp.	4.88	3.04	2.18	0.82	3.05	40.11
Leptocylindrus minimus	8.01	3.54	2.14	0.87	3	43.11

Lauderia/Detonula sp.	7.26	5.05	1.93	1.09	2.7	45.81
Thalassionema nitzschioides	6.41	1.27	1.92	0.77	2.69	48.51
Centric diatom spp.	16.21	15.28	1.87	1.24	2.62	51.12

Table K.3 : Output of two-way SIMPER analysis displaying contribution of phytoplankton taxa to 50% of the dissimilarity between years across all seasons.

Groups 2010 & 2011	Average dissimilarity = 71.44					
	Group 2010	Group 2011				
Species	Average Abundance (square root)	Average Abundance (square root)	Average Dissimilarity	Dissimilarity/Standard Deviation	Contribution (%)	Cumulative (%)
Guinardia delicatula	2.59	36.46	4.05	0.71	5.68	5.68
Paralia sulcata	18.33	17.28	3.96	1.02	5.54	11.22
Paralia sp.	9.12	14.38	3.78	0.71	5.29	16.51
Leptocylindrus danicus	13.76	11.49	2.93	1.16	4.1	20.62
Guinardia flaccida	6.98	22.53	2.91	0.75	4.07	24.69
Rhizosolenia spp.	16.83	7.71	2.8	0.66	3.92	28.61
Skeletonema spp.	9.63	8.81	2.49	0.88	3.49	32.1
Leptocylindrus minimus	8.51	13.3	2.28	1.12	3.19	35.29
Pennate diatom sp.	10.48	12.79	2.03	1.16	2.84	38.13
Chaetocerus (*Halochaete*) spp.	4.76	8.25	1.97	0.95	2.76	40.89
Thalassionema nitzschioides	3.79	7.33	1.74	0.87	2.44	43.34
Pseudo-nitzschia seriata complex	8.93	6.41	1.73	1.07	2.42	45.75
Centric diatom spp.	9.29	16.13	1.65	1.29	2.31	48.07
Ceratoneis closterium/ Nitzschia longissima	6.68	8.69	1.51	1.25	2.12	50.18

Groups 2010 & 2012	Average dissimilarity = 80.39					
	Group 2010	Group 2012				
Species	Average Abundance (square root)	Average Abundance (square root)	Average Dissimilarity	Dissimilarity/Standard Deviation	Contribution (%)	Cumulative (%)
Paralia sp.	9.12	28.63	5.32	1.32	6.62	6.62
Guinardia delicatula	2.59	19.56	4.56	1.56	5.67	12.29
Guinardia flaccida	6.98	30.96	3.94	0.84	4.91	17.2
Lauderia/Detonula sp.	5.3	28.71	3.42	0.98	4.25	21.45
Ceratoneis closterium/ Nitzschia longissima	6.68	23.66	2.91	0.96	3.62	25.07
Rhizosolenia imbricata	9.35	6.61	2.38	1.04	2.96	28.03
Leptocylindrus minimus	8.51	12.07	2.38	0.72	2.96	30.99
Leptocylindrus danicus	13.76	6.37	2.22	0.83	2.76	33.74
Phaeocystis globosa	5.31	0	2.14	0.67	2.66	36.4
Skeletonema spp.	9.63	14.85	2.07	0.69	2.58	38.98
Microflagellate sp.	0	41.85	2.06	0.21	2.57	41.55
Paralia sulcata	18.33	14.84	1.99	0.7	2.48	44.02
Pennate diatom sp.	10.48	15.55	1.98	1.3	2.46	46.48
Rhizosolenia spp.	16.83	6.73	1.89	0.72	2.35	48.83
Bacillaria paxillifera	1.51	19.9	1.83	0.61	2.27	51.1
Groups 2011 & 2012	**Average dissimilarity = 70.24**					
	Group 2011	**Group 2012**				
Species	**Average Abundance (square root)**	**Average Abundance (square root)**	**Average Dissimilarity**	**Dissimilarity/Standard Deviation**	**Contribution (%)**	**Cumulative (%)**
Guinardia delicatula	36.46	19.56	5.1	0.86	7.26	7.26
Paralia sp.	14.38	28.63	4.51	0.86	6.42	13.68

Groups 2010 & 2011	Average dissimilarity = 71.44					
	Group 2010	Group 2011				
Species	Average Abundance (square root)	Average Abundance (square root)	Average Dissimilarity	Dissimilarity/Standard Deviation	Contribution (%)	Cumulative (%)
Paralia sulcata	17.28	14.84	4.22	0.81	6.01	19.69
Guinardia flaccida	22.53	30.96	3.4	0.8	4.84	24.53
Lauderia/Detonula sp.	5.97	28.71	3.18	1.04	4.53	29.06
Bacillaria paxillifera	3.92	19.9	3.09	0.93	4.4	33.46
Ceratoneis closterium/ Nitzschia longissima	8.69	23.66	2.68	0.96	3.82	37.28
Skeletonema spp.	8.81	14.85	2.1	0.74	2.99	40.27
Microflagellate sp.	0	41.85	1.94	0.21	2.76	43.03
Leptocylindrus minimus	13.3	12.07	1.94	0.75	2.76	45.79
Thalassiosira spp.	4.91	9.78	1.72	0.85	2.45	48.24
Pennate diatom sp.	12.79	15.55	1.69	1.06	2.41	50.65
Groups 2010 & 2014	**Average dissimilarity = 79.01**					
	Group 2010	**Group 2014**				
Species	**Average Abundance (square root)**	**Average Abundance (square root)**	**Average Dissimilarity**	**Dissimilarity/Standard Deviation**	**Contribution (%)**	**Cumulative (%)**
Guinardia delicatula	2.59	34.84	4.07	1.14	5.15	5.15
Ceratoneis closterium/ Nitzschia longissima	6.68	48.09	4.01	2.41	5.08	10.23
Centric diatom spp.	9.29	38.58	3.63	2.77	4.59	14.82
Paralia sp.	9.12	42.68	3.39	0.95	4.29	19.11
Paralia sulcata	18.33	18.37	2.94	1.06	3.72	22.83
Pennate diatom sp.	10.48	28.38	2.23	1.53	2.82	25.65

Groups 2010 & 2011	Average dissimilarity = 71.44					
	Group 2010	Group 2011				
Species	Average Abundance (square root)	Average Abundance (square root)	Average Dissimilarity	Dissimilarity/Standard Deviation	Contribution (%)	Cumulative (%)
Leptocylindrus danicus	13.76	23.12	2.21	1.43	2.8	28.45
Rhizosolenia spp.	16.83	1.55	2.18	0.59	2.76	31.22
Thalassionema nitzschioides	3.79	16.57	2.16	1.15	2.73	33.95
Chaetocerus (Halochaete) spp.	4.76	16.94	2.12	1.41	2.68	36.63
Leptocylindrus minimus	8.51	18.16	2.11	1.15	2.67	39.31
Navicula spp.	0.1	13.43	1.89	0.86	2.4	41.71
Pseudo-nitzschia seriata complex	8.93	15.85	1.87	1.33	2.37	44.08
Bacillaria paxillifera	1.51	20.48	1.8	0.82	2.28	46.36
Pseudo-nitzschia delicatissima complex	1.2	23.12	1.77	0.94	2.24	48.6
Skeletonema spp.	9.63	17.78	1.69	0.9	2.14	50.75
Groups 2011 & 2014	**Average dissimilarity = 72.54**					
	Group 2011	**Group 2014**				
Species	**Average Abundance (square root)**	**Average Abundance (square root)**	**Average Dissimilarity**	**Dissimilarity/Standard Deviation**	**Contribution (%)**	**Cumulative (%)**
Guinardia delicatula	36.46	34.84	6.36	1.04	8.77	8.77
Paralia sp.	14.38	42.68	4.25	1.22	5.86	14.64
Ceratoneis closterium / Nitzschia longissima	8.69	48.09	3.93	2.21	5.41	20.05
Guinardia flaccida	22.53	12	3.13	0.88	4.31	24.36

Groups 2010 & 2011	Average dissimilarity = 71.44					
	Group 2010	Group 2011				
Species	Average Abundance (square root)	Average Abundance (square root)	Average Dissimilarity	Dissimilarity/Standard Deviation	Contribution (%)	Cumulative (%)
Paralia sulcata	17.28	18.37	2.52	1.01	3.47	27.83
Centric diatom spp.	16.13	38.58	2.44	1.86	3.36	31.19
Bacillaria paxillifera	3.92	20.48	2.12	0.92	2.92	34.11
Pseudo-nitzschia delicatissima complex	2.18	23.12	1.94	1.05	2.67	36.78
Leptocylindrus danicus	11.49	23.12	1.93	1.38	2.66	39.44
Leptocylindrus minimus	13.3	18.16	1.85	1.17	2.54	41.98
Thalassionema nitzschoides	7.33	16.57	1.84	1.16	2.54	44.52
Pennate diatom sp.	12.79	28.38	1.81	1.6	2.5	47.02
Skeletonema spp.	8.81	17.78	1.72	0.98	2.37	49.39
Plagiogrammopsis sp.	0	20.87	1.63	0.64	2.25	51.65
Groups 2012 & 2014	**Average dissimilarity = 67.04**					
	Group 2012	**Group 2014**				
Species	**Average Abundance (square root)**	**Average Abundance (square root)**	**Average Dissimilarity**	**Dissimilarity/Standard Deviation**	**Contribution (%)**	**Cumulative (%)**
Guinardia flaccida	30.96	12	4.13	0.97	6.17	6.17
Lauderia/Detonula sp.	28.71	5.01	3.75	1.38	5.59	11.76
Paralia sp.	28.63	42.68	3.5	1.45	5.22	16.97
Microflagellate sp.	41.85	0	2.99	0.27	4.47	21.44
Ceratoneis closterium/Nitzschia longissima	23.66	48.09	2.84	1.43	4.24	25.68

Groups 2010 & 2011	Average dissimilarity = 71.44					
	Group 2010	Group 2011				
Species	Average Abundance (square root)	Average Abundance (square root)	Average Dissimilarity	Dissimilarity/Standard Deviation	Contribution (%)	Cumulative (%)
Skeletonema spp.	14.85	17.78	2.34	0.88	3.48	29.17
Bacillaria paxillifera	19.9	20.48	2.23	1.2	3.32	32.49
Guinardia delicatula	19.56	34.84	2.14	1.11	3.19	35.68
Leptocylindrus minimus	12.07	18.16	1.87	0.97	2.79	38.47
Plagiogrammopsis sp.	1.39	20.87	1.77	0.73	2.63	41.1
Pseudo-nitzschia delicatissima complex	12.54	23.12	1.69	1.49	2.52	43.63
Thalassiosira rotula/gravida	0	16.05	1.62	1.37	2.41	46.04
Asterionellopsis glacialis	1.83	14.83	1.59	1.09	2.38	48.41
Skeletonema costatum	7.2	6.6	1.58	0.71	2.36	50.77

Table K.4 : HPLC results for all sites from May 2010 to October 2012. Fuco = Fucoxanthin, 19’Hex = 19’-hexanoyloxyfucoxanthin, Allo = Alloxanthin, Viola = Violaxanthin, Zea = Zeaxanthin, 19’But = 19'-butanoyloxyfucoxanthin. All values are in ng L^{-1}.

Date	Site/Tide	Chl c2	Chl c3	Peridinin	Fuco	19’Hex	Allo	Viola	Zea	Chl b	Divinyl Chl	Chl a	Beta carotene	19’ But
12/05/2010	S1 EBB				250.6		11.7			8.6	71.0	562.9	14.0	
12/05/2010	S2 FLOOD				311.0						38.3	634.0	14.6	
12/05/2010	S2 EBB				250.5						38.8	565.3	10.3	
12/05/2010	S3 FLOOD				200.1						26.8	400.7	10.1	
12/05/2010	S3 EBB	18.9		48.1	343.5		16.0				75.9	1732.5	15.3	
12/05/2010	S4 FLOOD			66.9	352.2		19.2			9.1	60.4	948.2	19.8	
12/05/2010	S4 EBB			35.5	283.1		12.9				86.8	627.9	16.0	
12/05/2010	S5 FLOOD			44.2	272.0		13.3				62.5	650.1	12.0	
12/05/2010	S5 EBB			59.2	432.0		19.3			14.3	106.2	1178.5	19.6	
16/06/2010	S1 FLOOD				380.2	20.5					26.0	811.4	18.2	
16/06/2010	S1 EBB	16.4			377.0					35.6		1008.1	19.1	
16/06/2010	S2 FLOOD	19.5			241.4							666.6	13.2	
16/06/2010	S2 EBB	16.0			244.9						36.5	580.3	13.8	
16/06/2010	S3 FLOOD	23.7			285.5							634.5	15.3	
16/06/2010	S3 EBB	28.1			273.2		13.3			19.2	53.0	655.2	15.6	
16/06/2010	S4 FLOOD	11.4			300.9	27.7	13.9			19.0	63.0	752.1	16.8	
16/06/2010	S4 EBB	17.3			253.7					18.1	37.4	615.0	13.2	
16/06/2010	S5 FLOOD	20.6		21.1	290.4					18.8	56.9	656.1	14.9	
16/06/2010	S5 EBB				263.9						19.6	577.9	10.1	
04/08/2010	S1 FLOOD				128.9		14.8			62.2	20.1	471.3	12.4	
03/08/2010	S1 EBB				174.0	20.8	30.8			55.2	26.4	661.3	16.1	
04/08/2010	S2 FLOOD	10.0			107.1		14.3	4.9		57.9	22.7	357.9	9.2	

Date	Site/Tide	Chl c2	Chl c3	Peridinin	Fuco	19'Hex	Allo	Viola	Zea	Chl b	Divinyl Chl	Chl a	Beta carotene	19' But
03/08/2010	S2 EBB	24.5			108.1		15.0			43.8	99.5	4722.3	10.7	
03/08/2010	S3 FLOOD	6.2			111.0		16.2			62.8	14.1	458.8	11.8	
04/08/2010	S4 FLOOD	24.0			755.2	52.2	66.4	45.7	62.5	469.4	177.7	2811.1	47.8	
03/08/2010	S4 EBB		110.1		219.9		18.9	14.3		227.2	71.3	1338.2	14.1	
03/08/2010	S5 FLOOD				133.6		15.7			56.1	12.8	498.0	14.1	
18/08/2010	S1 FLOOD				211.1		27.0			59.2		561.0	17.2	
18/08/2010	S1 EBB				285.4		30.8			83.0		788.0	25.5	
18/08/2010	S2 FLOOD				218.0		35.5	7.6		69.4		615.4	21.3	
18/08/2010	S2 EBB				334.8		34.2			114.2		782.0	25.2	
18/08/2010	S3 FLOOD				217.6		19.4	5.5		73.6		526.8	14.8	
18/08/2010	S3 EBB				225.4		2.6			56.8		571.6	17.8	
18/08/2010	S4 FLOOD				213.0		21.8			76.4		602.3	18.0	
18/08/2010	S4 EBB				208.6		19.1			33.0		531.6	14.8	
18/08/2010	S5 FLOOD				304.8		28.8	11.9		78.2		798.0	28.0	
18/08/2010	S5 EBB				300.4		23.4			0.0		613.4	17.3	
22/09/2010	S1 FLOOD				183.1		17.0			81.5		421.3	1.6	
22/09/2010	S1 EBB				248.7		23.8			126.8		574.2	23.3	
22/09/2010	S2 FLOOD				133.6		17.3			69.5		697.1	14.4	
22/09/2010	S2 EBB				178.8					85.4		514.3	16.7	
22/09/2010	S3 FLOOD				150.3					46.6		426.8	15.2	
22/09/2010	S3 EBB				172.8		22.9			60.7		487.2	15.8	
22/09/2010	S4 FLOOD				168.2		24.9			95.3		357.0	14.2	
22/09/2010	S4 EBB				145.3		16.6					400.0	14.3	
22/09/2010	S5 FLOOD				141.7		23.7					390.5	12.8	
22/09/2010	S5 EBB				124.8		15.4					253.0	9.8	

Date	Site/Tide	Chl c2	Chl c3	Peridinin	Fuco	19'Hex	Allo	Viola	Zea	Chl b	Divinyl Chl	Chl a	Beta carotene	19' But
13/10/2010	S1 FLOOD				401.6					104.2		1014.9	26.8	
13/10/2010	S1 EBB				532.9							1423.5	40.9	
13/10/2010	S2 FLOOD				357.1					148.4		887.3	26.3	
13/10/2010	S2 EBB	10.6			242.4							630.2	20.7	
13/10/2010	S3 FLOOD	37.9			130.9					89.0		357.0	11.7	
13/10/2010	S3 EBB	27.1			162.1					57.7		437.8	26.1	
13/10/2010	S4 FLOOD	74.8			319.1					110.6		847.9	31.3	
13/10/2010	S4 EBB	31.4			307.6	54.4				92.7		832.8	20.4	
13/10/2010	S5 FLOOD	46.0			381.4	71.2				113.0		1019.8	26.4	
13/10/2010	S5 EBB				213.3	36.6				87.6		566.9	14.8	
15/11/2010	S1 FLOOD				126.7	21.5						346.7	14.2	
15/11/2010	S1 EBB				123.5	24.4				66.5		328.0	11.1	
15/11/2010	S2 FLOOD				104.8	12.7				56.7		243.6	6.3	
15/11/2010	S2 EBB				82.1							213.6	5.2	
15/11/2010	S3 FLOOD				87.9							294.5		
15/11/2010	S3 EBB				100.9					55.2		281.1	6.1	
15/11/2010	S4 FLOOD	43.5			118.8	17.3						289.4	7.7	
15/11/2010	S4 EBB				95.6							246.7	4.6	
15/11/2010	S5 FLOOD				100.1					28.2		267.8	6.5	
15/11/2010	S5 EBB				112.0					92.9		242.9	13.1	
15/12/2010	S1 FLOOD	60.0			208.2							427.4	6.9	
15/12/2010	S1 EBB				189.9							413.1	12.6	
15/12/2010	S2 FLOOD				148.0							354.7		
15/12/2010	S2 EBB				176.3							412.6	10.1	
15/12/2010	S3 FLOOD				94.3							216.2	5.7	

Date	Site/Tide	Chl c2	Chl c3	Peridinin	Fuco	19'Hex	Allo	Viola	Zea	Chl b	Divinyl Chl	Chl a	Beta carotene	19' But
15/12/2010	S3 EBB				123.5							261.5		
15/12/2010	S4 FLOOD	43.2			220.8					61.7		478.6	12.0	
15/12/2010	S4 EBB				125.5		8.1			19.2	16.6	359.2	7.3	
15/12/2010	S5 FLOOD				151.5		10.0			19.6	10.4	407.2	11.1	
15/12/2010	S5 EBB				195.4		12.8			25.1	14.9	504.2	14.3	
24/01/2011	S1 FLOOD				132.8							466.2	11.0	
24/01/2011	S1 EBB				120.3							333.6	7.7	
24/01/2011	S2 FLOOD				127.7							230.5	7.6	
24/01/2011	S2 EBB				115.2							272.6	6.1	
24/01/2011	S3 FLOOD				131.7							263.8	7.6	
24/01/2011	S3 EBB				120.6							299.2	8.1	
24/01/2011	S4 FLOOD				146.3							420.1	10.5	
24/01/2011	S4 EBB				103.2							261.7	7.6	
24/01/2011	S5 FLOOD				128.4							307.5	6.2	
24/01/2011	S5 EBB				124.3							282.3	6.0	
16/02/2011	S1 * (tide not determined)				159.4							710.0	11.9	
16/02/2011	S1 * (tide not determined)				176.0							443.3	10.1	
16/02/2011	S2 FLOOD				186.2							277.9	15.6	
16/02/2011	S2 EBB				167.9							562.2	9.0	
16/02/2011	S3 * (tide not determined)				143.4							274.0	8.9	

Date	Site/Tide	Chl c2	Chl c3	Peridinin	Fuco	19'Hex	Allo	Viola	Zea	Chl b	Divinyl Chl	Chl a	Beta carotene	19' But
16/02/2011	S3 * (tide not determined)				200.8							413.7	10.3	
16/02/2011	S4 FLOOD				142.1							484.9	9.2	
16/02/2011	S4 EBB				156.0							329.4	8.1	
16/02/2011	S5 * (tide not determined)				162.9							290.3	10.2	
16/02/2011	S5 * (tide not determined)				152.5							412.0	10.2	
16/03/2011	S1 FLOOD		107.6		222.8							548.5	20.5	
16/03/2011	S1 EBB	16.4	39.4		281.8		28.8					704.8	17.2	
16/03/2011	S2 FLOOD	19.5			247.6	14.5					40.6	561.4	12.1	
16/03/2011	S2 EBB	15.1			261.7	19.6					55.1	564.8	14.8	
16/03/2011	S3 FLOOD	21.6	47.6		123.0							204.3	4.7	
16/03/2011	S3 EBB	25.3			178.9		15.7				39.4	421.2	8.4	
16/03/2011	S4 FLOOD	37.9			281.9						157.2	779.5	9.9	
16/03/2011	S4 EBB	24.1			197.9		17.0				33.1	470.8	10.6	
16/03/2011	S5 FLOOD				216.5		14.7				39.9	489.3	10.6	
16/03/2011	S5 EBB				251.4		18.3				46.1	659.2	12.9	
14/04/2011	S1 FLOOD				1015.1						81.0	2123.9	45.5	
14/04/2011	S1 EBB			37.8	1540.6						96.6	3346.4	63.9	
14/04/2011	S2 FLOOD				477.0						27.9	1219.9	21.8	
14/04/2011	S2 EBB				725.3						53.7	1545.6	29.3	
14/04/2011	S3 FLOOD				340.1							766.3	14.9	

Date	Site/Tide	Chl c2	Chl c3	Peridinin	Fuco	19'Hex	Allo	Viola	Zea	Chl b	Divinyl Chl	Chl a	Beta carotene	19' But
14/04/2011	S3 EBB	25.8			524.1							1278.8		
14/04/2011	S4 FLOOD	55.3			938.9							2007.5	36.8	
14/04/2011	S4 EBB				894.5							2041.6	32.2	
14/04/2011	S5 FLOOD				695.0							1964.2	27.2	
14/04/2011	S5 EBB				928.1							2334.9	32.1	
18/05/2011	S1 FLOOD	13.1			1270.6							1990.5	35.5	
18/05/2011	S1 EBB				1421.3							2209.1	52.3	
18/05/2011	S2 FLOOD				1251.4		39.6					2046.8	46.7	
18/05/2011	S2 EBB	24.0			1677.4		40.9					2755.3	54.5	
18/05/2011	S3 FLOOD				957.2		28.4					1487.5	37.6	
18/05/2011	S3 EBB				1470.3		34.1					2299.9	46.2	
18/05/2011	S4 FLOOD	21.1			1573.1		49.3					2600.0	53.5	
18/05/2011	S4 EBB	8.4			1519.5		42.1					2191.7	48.2	
18/05/2011	S5 FLOOD				1385.2		36.0		22.3			2408.9	51.8	
18/05/2011	S5 EBB	13.7			1757.0		12.8		20.2			3390.0	49.8	
15/06/2011	S1 FLOOD				320.9							704.2	18.5	
15/06/2011	S1 EBB				371.3							776.2	17.2	
15/06/2011	S2 FLOOD				219.8					51.4		488.5	13.1	
15/06/2011	S2 EBB				315.5					41.6	49.3	684.9	12.5	
15/06/2011	S3 FLOOD				192.3					41.2	30.3	461.2	8.5	
15/06/2011	S3 EBB				196.5					33.5	27.0	466.4	11.0	
15/06/2011	S4 FLOOD				368.7					41.6	55.5	729.9	13.8	
15/06/2011	S4 EBB				289.6					27.6	44.5	623.5	10.5	
15/06/2011	S5 FLOOD				182.6					47.9	34.7	406.2	9.2	
15/06/2011	S5 EBB				284.1						54.1	575.6	10.0	

Date	Site/Tide	Chl c2	Chl c3	Peridinin	Fuco	19'Hex	Allo	Viola	Zea	Chl b	Divinyl Chl	Chl a	Beta carotene	19' But
13/07/2011	S1 FLOOD				226.4		34.0			89.5		707.6	26.7	
13/07/2011	S1 EBB				288.5		36.7			115.3	73.5	776.0	26.4	
13/07/2011	S2 FLOOD				169.4		21.5		15.5	73.2	29.7	502.7	15.2	
13/07/2011	S2 EBB				185.5		30.3			81.2	37.5	550.5	17.0	
13/07/2011	S3 FLOOD				178.0		14.7		14.3	78.6	31.5	509.7	15.5	
13/07/2011	S3 EBB				186.0		33.7		21.3	89.3	45.8	619.4	20.7	
13/07/2011	S4 FLOOD				224.2		34.8			75.3	57.1	706.4	19.0	
13/07/2011	S4 EBB				197.9		36.5			81.5	60.2	602.3	18.8	
13/07/2011	S5 FLOOD				204.0		21.2		16.3	114.9		661.2	17.8	
13/07/2011	S5 EBB				190.2		23.7		20.1	86.4	53.8	646.3	17.3	
18/08/2011	S1 FLOOD				245.9		45.4		11.1	139.2		913.3	30.5	
18/08/2011	S1 EBB				221.3		42.5			110.5		718.3	21.6	
18/08/2011	S2 FLOOD				213.7		48.7			99.1		698.1	22.2	
18/08/2011	S2 EBB				244.9		48.5			110.4		723.7	22.3	
18/08/2011	S3 FLOOD				202.6		45.1			110.7		718.4	21.4	
18/08/2011	S3 EBB				249.7		42.7			113.9		794.8	26.6	
18/08/2011	S4 FLOOD			53.7	277.3		53.0			146.9		909.8	32.7	
18/08/2011	S4 EBB			40.1	216.2		45.5			99.5		698.8	26.5	
18/08/2011	S5 FLOOD			50.4	293.6		58.7			125.3		1053.3	33.3	
18/08/2011	S5 EBB				250.8		54.2			114.8		705.2	25.9	
18/08/2011	S6 FLOOD				274.6		50.3			145.2		899.5	24.0	
18/08/2011	S6 EBB				206.8		24.1			132.5		665.8	19.5	
22/09/2011	S1 FLOOD				177.0		43.1			99.0		810.7	21.5	
22/09/2011	S1 EBB				142.5		29.5			20.5		428.6	13.5	
22/09/2011	S2 FLOOD				139.5		26.1			49.1		373.2	10.8	

Date	Site/Tide	Chl c2	Chl c3	Peridinin	Fuco	19’Hex	Allo	Viola	Zea	Chl b	Divinyl Chl	Chl a	Beta carotene	19’ But
22/09/2011	S2 EBB				172.8		32.0			65.2		480.6	17.7	
22/09/2011	S3 FLOOD				158.7		30.4			56.3		381.6	13.3	
22/09/2011	S3 EBB				144.4		26.9			53.6		374.5	13.0	
22/09/2011	S4 FLOOD				188.0		40.0			76.7		757.0	18.7	
22/09/2011	S4 EBB				175.7		35.5			54.7		522.4	15.0	
22/09/2011	S5 FLOOD				182.3		33.1			58.7		527.0	16.3	
22/09/2011	S5 EBB				141.7		29.1			59.5		454.3	16.0	
22/09/2011	S6FLOOD				166.1		29.1			39.2		430.7	12.9	
22/09/2011	S6 EBB				129.3		23.6			41.8		333.5	11.9	
12/10/2011	S1 FLOOD		61.4		127.6		13.9					500.8	9.1	
12/10/2011	S1 EBB				120.8		16.4			17.4		226.5	7.6	
12/10/2011	S2 FLOOD				101.9		14.6			17.5		253.7	7.5	
12/10/2011	S2 EBB		6.0		100.2		9.1			11.7		337.5	7.4	
12/10/2011	S3 FLOOD				108.6		10.7			17.9		341.6	6.8	
12/10/2011	S3 EBB				110.1		11.7			13.2		186.2	6.4	
12/10/2011	S4 FLOOD				103.4		8.9					299.2	5.9	
12/10/2011	S4 EBB				127.2		14.2			30.2		385.0	11.2	
12/10/2011	S5 FLOOD				103.9		9.6					256.4	8.4	
12/10/2011	S5 EBB				127.8		11.3			23.9		329.7	7.7	
12/10/2011	S6FLOOD				112.7		9.1			20.0		246.6	6.8	
12/10/2011	S6 EBB				126.5		9.2			19.5		350.9	8.1	
15/11/2011	S1 EBB				81.5		5.7	6.4	5.9			272.2	10.2	3.6
15/11/2011	S2 FLOOD				87.9	11.7	6.0	6.3	6.1			290.7	10.5	
15/11/2011	S3 FLOOD		11.4		96.2							269.2	9.5	
15/11/2011	S4 FLOOD				76.7							216.0	7.0	

Date	Site/Tide	Chl c2	Chl c3	Peridinin	Fuco	19'Hex	Allo	Viola	Zea	Chl b	Divinyl Chl	Chl a	Beta carotene	19' But
15/11/2011	S5 FLOOD		5.8		90.8					26.7		235.1	11.2	
15/11/2011	S6FLOOD				77.6			5.9		30.3		250.4	7.1	
15/11/2011	S6 EBB				67.7					29.8		221.2	8.6	
11/01/2012	S1 EBB				157.9		6.2				23.4	301.2	7.7	
11/01/2012	S2 EBB				97.9						9.0	175.2	4.3	
11/01/2012	S3 EBB				86.1							167.1	4.0	
11/01/2012	S4 EBB				111.7			3.8			14.4	205.8	5.7	
11/01/2012	S5 FLOOD				91.0						18.8	185.7	4.8	
11/01/2012	S6 EBB				89.6							200.3		
11/01/2012	S6FLOOD				82.5							148.5	4.3	
26/02/2012	S1 FLOOD				146.9		7.6	9.4				361.5	5.1	
26/02/2012	S1 EBB			10.6	163.2			9.9				382.4	12.7	
26/02/2012	S2 FLOOD				134.3			9.5				357.7	6.4	
26/02/2012	S2 EBB		33.1		157.4			10.3				359.2	9.3	
26/02/2012	S3 FLOOD				148.8		4.8	8.8				363.3	8.6	
26/02/2012	S3 EBB				142.4			8.5				362.1	9.0	
26/02/2012	S4 FLOOD				206.2		8.2	12.9				414.3	10.3	
26/02/2012	S4 EBB				139.8		5.0	8.5				366.6	9.1	
26/02/2012	S5 FLOOD				145.4			8.9				349.3	8.4	
26/02/2012	S5 EBB				149.4			9.2				315.6	12.4	
26/02/2012	S6FLOOD		28.9		163.6			8.7				311.6	6.0	
26/02/2012	S6 EBB				120.8							269.0	7.3	
21/03/2012	S1 EBB				373.1		12.0	3.8				754.2	25.2	
21/03/2012	S1 FLOOD	20.1			434.1		9.5				72.6	977.3	27.0	
21/03/2012	S2 EBB				273.9		8.5				38.0	597.4	17.6	

Date	Site/Tide	Chl c2	Chl c3	Peridinin	Fuco	19'Hex	Allo	Viola	Zea	Chl b	Divinyl Chl	Chl a	Beta carotene	19' But
21/03/2012	S2 FLOOD				225.4						36.0	560.5	10.7	
21/03/2012	S3 EBB				383.9		16.8				52.5	896.8	26.6	
21/03/2012	S3 FLOOD				238.0		7.6				59.3	650.1	13.2	
21/03/2012	S4 EBB	19.3			318.4		11.0			31.8	58.8	790.8	17.0	
21/03/2012	S4 FLOOD				347.8		11.3			20.7	51.5	820.7	24.8	
21/03/2012	S5 EBB				282.9		10.6			31.9	38.2	639.0		
21/03/2012	S5 FLOOD				219.6		9.2				30.2	514.7	14.8	
21/03/2012	S6 EBB				260.3		8.7			26.6	37.4	576.5	16.1	
21/03/2012	S6FLOOD				254.5		7.6			25.7	34.9	650.7	14.3	
02/05/2012	S1 EBB		49.9		1183.0		27.2	27.5			52.5	2566.1		9.2
02/05/2012	S1 FLOOD		186.4		1221.6		9.2				156.7	2626.2		17.2
02/05/2012	S2 EBB		329.6		1507.4						173.7	3258.3		20.1
02/05/2012	S2 FLOOD		70.8		1632.5						105.5	3258.6		
02/05/2012	S3 EBB		34.5		1241.7						82.3	2366.5		11.5
02/05/2012	S3 FLOOD		41.5		858.5						42.3	1681.0		
02/05/2012	S4 EBB		609.0		1522.0	36.6	23.9	10.8	23.7		398.9	3862.8		151.7
02/05/2012	S4 FLOOD		41.5		1302.0						102.2	2632.8		21.9
02/05/2012	S5 EBB	24.2	189.7		1477.5		28.7		14.5		133.0	2987.5		34.7
02/05/2012	S5 FLOOD		130.7		1156.3						80.6	2170.5		30.9
02/05/2012	S6 EBB		243.2		1084.1		19.2	6.6	15.8		108.2	2284.3		9.5
02/05/2012	S6FLOOD		37.8		904.7			1.6			55.2	1783.6		9.4
16/05/2012	S6 EBB	18.6		9.1	1862.5		53.4	147.5	11.1		53.4	3197.1	89.9	
16/05/2012	S6FLOOD			48.2	1467.4		30.0	125.3	18.4	38.6	74.2	2608.3	70.2	
12/06/2012	S6 EBB			42.0	174.4		27.9	26.2	26.0			473.1	16.8	
12/06/2012	S6FLOOD			36.9	204.7		42.1	28.8	24.7			398.4	13.2	

Date	Site/Tide	Chl c2	Chl c3	Peridinin	Fuco	19'Hex	Allo	Viola	Zea	Chl b	Divinyl Chl	Chl a	Beta carotene	19' But
17/07/2012	S6 EBB			20.3	244.3	15.7		21.2	10.6	30.7		782.9		
17/07/2012	S6FLOOD	32.3		40.5	290.8		17.1	24.1	27.6		23.5	961.5	30.1	
22/08/2012	S6 EBB			20.7	232.6		24.7	18.0		33.5	17.2	703.0	19.5	3.5
22/08/2012	S6FLOOD	11.8	18.6	21.4	424.5	27.3	51.8	31.0		45.9	10.3	1057.5	23.3	
19/09/2012	S6 EBB			25.5	244.2	27.5	36.4	21.1		56.5		759.8	30.0	7.9
19/09/2012	S6FLOOD			16.4	245.2		18.0	17.8		45.2		685.8	25.7	
09/10/2012	S6 EBB				136.8	22.5	16.9	12.1		42.4		457.8	16.7	
09/10/2012	S6FLOOD	12.6			132.5	24.0	24.0	15.1		64.1		465.0	23.4	5.9

Table K.5 : Chlorophyll-a results for all sites from February 2014 to September 2014. All values are in µg L^{-1}.

Date	Site	Chl a
19/02/2014	S2	<0.500
19/02/2014	S4	0.74
19/02/2014	S6	0.53
19/02/2014	S7	<0.500
26/03/2014	S2	1.3
26/03/2014	S4	1.3
26/03/2014	S6	1.1
26/03/2014	S7	1.1
16/04/2014	S2	1.9
16/04/2014	S4	2
16/04/2014	S6	2
16/04/2014	S7	1.9
20/05/2014	S2	8.2
20/05/2014	S4	6.3
20/05/2014	S6	5.9
20/05/2014	S7	5.2
10/06/2014	S2	4.6
10/06/2014	S4	4
10/06/2014	S6	3.7
10/06/2014	S7	3.9
15/07/2014	S2	2.6
15/07/2014	S4	3
15/07/2014	S6	2.3
15/07/2014	S7	2.1
05/08/2014	S2	1.3
05/08/2014	S4	2
05/08/2014	S6	1.4
05/08/2014	S7	1.5
02/09/2014	S2	1.6
02/09/2014	S4	1.6
02/09/2014	S6	1.6
02/09/2014	S7	1.4

Table K.6 : Principal Component Analysis (PCA) output of phytoplankton pigments detected by HPLC between May 2010 and October 2012.

Eigenvalues	Eigenvalues (information explained)	% Variation	Cumulative % Variation
PC			
1	5.29	28.3	28.3
2	4.17	22.3	50.7

Eigenvalues PC	Eigenvalues (information explained)	% Variation	Cumulative % Variation
3	2.02	10.8	61.5
4	1.79	9.6	71
5	1.47	7.9	78.9

Eigenvectors (component loadings) Variable	PC1	PC2	PC3	PC4	PC5
Chlorophyll c2	0.058	0.073	-0.058	-0.564	-0.661
Chlorophyll c3	0.22	0.257	0.062	0.581	-0.406
Peridinin	-0.042	0.145	0.284	-0.197	0.039
Fucoxanthin	0.092	0.187	0.134	-0.074	-0.143
19'Hex	-0.023	0.031	-0.05	-0.048	-0.343
Alloxanthin	-0.42	0.346	0.597	0.041	0.166
Violaxanthin	0.001	0.087	0.367	0.069	-0.176
Zeaxanthin	-0.005	0.12	0.22	0.008	-0.067
Chlorophyll b	-0.806	0.198	-0.435	0.155	-0.195
Divinyl Chlorophyll	0.261	0.79	-0.355	-0.192	0.315
Chlorophyll a	0.042	0.204	0.113	-0.069	-0.152
Beta carotene	-0.183	-0.03	0.148	-0.408	0.068
19'-But	0.093	0.153	0.045	0.244	-0.175

Appendix L. Zooplankton

Table L.1 : Taxonomic list for all zooplankton found off north Anglesey between May 2010 and June 2014.

Phylum	Class	Order	Family	Taxon
Annelida	Polychaeta	Phyllodocida	Pholoidae	*Pholoe baltica*
				Pholoe inornata
			Phyllodocidae	Phyllodocidae indet.
			Polynoidae	Nectochaeta larvae
				Polynoidae
			Sphaerodoridae	Sphaerodoridae
			Syllidae	Autolytinae indet.
				Autolytus sp.
				Eusyllis blomstrandi
				Syllidae indet.
				Syllis sp.
			Tomopteridae	*Tomopteris helgolandica*
				Aphroditoidea indet.
		Sabellida	Sabellariidae	*Sabellaria* sp.
		Spionida	Magelonidae	Magelonidae
			Poecilochaetidae	Poecilochaetidae
				Poecilochaetus sp.
			Spionidae	*Malacoceros* sp.
				Polydora sp.
				Pygospio elegans
				Spio sp.
				Spionidae indet.
		Terebellida	Pectinariidae	*Lagis* sp.
				Pectinariidae
			Terebellidae	*Lanice* sp.
				Terebellidae
				Aciculata trocophore
				Metatrocophore larvae
				Polychaete indet.
Arthropoda	Arachnida	Trombidiformes	Halacaridae	Halacaridae indet.
				Arachnid indet.
	Branchiopoda	Diplostraca	Bosminidae	*Bosmina* sp.
			Podonidae	*Evadne nordmanni*
				Evadne sp.
				Evadne spinifera
				Podon intermedius

Phylum	Class	Order	Family	Taxon
				Podon leukart
				Podon spp.
	Malacostraca	Amphipoda	Amphilochidae	Amphilochidae
			Aoridae	Aoridae
			Calliopiidae	Calliophidae
			Caprellidae	*Caprella* sp.
				Caprellidae indet.
				Phtisica marina
			Isaeidae	Isaeidae
			Ischyroceridae	Ischyroceridae
				Amphipoda indet.
				Gammaridea indet.
		Cumacea		Cumacea indet
		Decapoda	Acanthephyridae	*Acanthephyra* sp.
			Alpheidae	*Athanas nitiscens*
			Atelecyclidae	*Atelecyclus* sp.
			Cancridae	*Cancer* sp.
			Corystidae	*Corystes cassivelaunus*
			Crangonidae	*Crangon allmanni*
				Crangon crangon
			Galatheidae	*Galathea* sp.
			Geryonidae	Geryonidae indet.
			Hippolytidae	*Eualus* sp
				Hippolyte sp.
				Thoralus sp.
			Inachidae	*Macropodia* sp.
			Leucosiidae	*Ebalia* sp.
			Majidae	*Eurynome* sp.
			Munididae	*Munida* sp.
			Nephropidae	*Homarus gammarus*
			Ocypodidae	*Uca tangeri*
			Oregoniidae	*Hyas* sp.
			Palaemonidae	*Palaemon* sp.
			Pandalidae	*Pandalina* sp.
				Pandalina brevirostris
			Parthenopidae	Parthenope indet.
			Pasiphaeidae	*Pasiphaea* sp.
			Pilumnidae	*Pilumnus* sp.
			Pinnotheridae	*Nepinnotheres pinnotheres*

Phylum	Class	Order	Family	Taxon
				Pinnotheres pisum
			Pirimelidae	*Pirimela denticulata*
			Porcellanidae	*Pisidia longicornis*
				Porcellana platycheles
				Porcellanidae indet.
			Portunidae	*Carcinus* sp.
				Portumnus latipes
				Portumnus sp.
			Rhynchocinetidae	*Cinetorhynchus* sp.
			Thalassinidae	Thalassinidae indet.
			Thiidae	*Thia scutellata*
			Varunidae	*Brachynotus sexdentatus*
			Xanthidae	*Monodaeus couchii*
				Nanocassiope melanodactyla
				Xantho sp.
				Anomura indet.
				Brachyura indet.
				Caridean indet.
				Decapoda indet.
		Euphausiacea	Euphausiidae	Euphausiidae
		Isopoda	Gnathiidae	Gnathiidae
			Idoteidae	Idotea
			Munnidae	Munnidae
				Epicarid isopod
				Isopoda indet.
		Mysida	Mysidae	*Gastrosaccus* sp.
				Mysidae indet.
		Tanaidacea	Apseudidae	Apseudidae indet.
				Crustacean egg
	Maxillopoda	Calanoida	Acartiidae	*Acartia clausi*
			Acartiidae	*Acartia discaudata*
			Acartiidae	*Acartia* spp.
			Calanidae	*Calanus finmarchicus*
			Calanidae	*Calanus helgolandicus*
			Calanidae	Calanus spp.
			Centropagidae	*Centropages hamatus*
			Centropagidae	Centropages sp.
			Centropagidae	*Isias clavipes*
			Clausocalanidae	*Microcalanus* sp.

Phylum	Class	Order	Family	Taxon
			Clausocalanidae	*Pseudocalanus elongatus*
			Diaixidae	*Diaixis hibernica*
			Metridinidae	*Metridia lucens*
			Paracalanidae	*Paracalanus parvus*
			Parapontellidae	*Parapontella brevicornis*
			Pontellidae	*Anomalocera patersoni*
			Temoridae	*Eurytemora affinis*
			Temoridae	*Temora longicornis*
				Calanoida indet
				Pseudo/Paracalanus #juv.
				Copepod eggs
		Cyclopoida	Oithonidae	*Oithona nana*
				Oithona plumifera
				Oithona similis
				Oithona sp.
				Benthic cyclopoida
		Harpacticoida	Darcythompsoniidae	*Leptocaris* sp.
			Ectinosomatidae	*Microsetella rosea*
			Euterpinidae	*Euterpina acutifrons*
			Harpacticidae	Harpacticidae indet.
				Harpacticus sp.
				Zaus sp.
				Zausopsis sp.
			Longipediidae	*Longipedia minor*
				Longipedia scotti
				Longipedia sp.
			Peltidiidae	*Alteutha depressa*
				Alteutha interrupta
				Alteutha sp.
				Alteuthella sp.
				Clytemnestra scutellata
				Peltidiidae indet.
			Tisbidae	*Sacodiscus* sp.
				Benthic harpacticoid
				Harpacticoida indet.
				Harpacticoida indet. (a)
				Harpacticoida indet. (b)
				Harpacticoida indet. (c)
				Harpacticoida indet. (d)

Phylum	Class	Order	Family	Taxon
		Monstrilloida	Monstrillidae	*Cymbasoma* sp.
				Monstrilla grandis
				Monstrilla longicornis
				Monstrilla sp.
		Poecilostomatoida	Corycaeidae	*Corycaeus anglicus*
				Corycaeus sp.
			Oncaeidae	*Oncaea* spp.
		Sessilia		Cyprid larvae indet.
				Thoracica nauplius
	Ostracoda	Podocopida		Podocopida
				Ostracod
Brachiopoda	Brachiopoda			Brachiopoda
				Lingulacea larvae
Bryozoa				Bryozoa indet. larvae
Chaetognatha	Sagittoidea	Aphragmophora	Sagittidae	*Parasagitta elegans*
				Parasagitta setosa
				Parasagitta sp.
		Phragmophora	Spadellidae	*Spadella cephaloptera*
				Chaetognatha indet.
Chordata	Actinopterygii	Clupeiformes	Clupeidae	*Clupea harengus*
		Gadiformes	Gadidae	*Merlangius merlangus*
		Perciformes	Ammodytidae	*Ammodytes lancea*
				Ammodytes marinus
				Ammodytidae
			Gobiidae	Gobiidae
				Pomatoschistus minutus
			Labridae	*Symphodus melops*
			Stichaeidae	*Chirolophis ascanii*
		Pleuronectiformes	Bothidae	*Arnoglossus laterna*
			Pleuronectidae	*Limanda limanda*
				Platichthys flesus
			Soleidae	*Solea solea*
				Soleidae
				Fish indet.
				Fish egg indet.
	Appendicularia	Copelata	Oikopleuridae	Oikopleura larvae
				Appendicularia
	Ascidiacea			Ascidian tadpole
Cnidaria	Anthozoa			Anthozoa indet.
	Hydrozoa	Anthoathecata	Corymorphidae	*Euphysa* sp.

Phylum	Class	Order	Family	Taxon
			Corynidae	*Coryne prolifera*
				Coryne sp.
				Corynidae
				Sarsia spp.
				Sarsia tubulosa
				Stauridiosarsia ophiogaster
			Hydractiniidae	*Hydractinia* sp.
			Oceaniidae	*Turritopsis nutricula*
			Pandeidae	*Amphinema* sp.
			Rathkeidae	*Lizzia blondina*
			Tubulariidae	*Hybocodon prolifer*
			Zancleidae	*Zanclea* sp.
				Anthoathecata
		Leptothecata	Campanulariidae	*Clytia hemisphaerica*
				Obelia sp.
			Lovenellidae	*Lovenella* sp.
			Mitrocomidae	*Cosmetira pilosella*
				Mitrocomella brownei
			Phialellidae	*Phialella quadrata*
				Phialella sp.
			Tiarannidae	*Modeeria rotunda*
				Leptothecata
		Limnomedusae	Olindiidae	*Gossea corynetes*
		Siphonophorae	Diphyidae	Diphyinae
		Trachymedusae	Geryoniidae	*Liriope tetraphylla*
				Actinula larvae
				Hydrozoa indet.
	Scyphozoa	Semaeostomeae	Ulmaridae	*Aurelia aurita*
				Semaeostomeae indet.
				Scyphozoa indet.
				Cnidaria indet.
Ctenophora	Nuda	Beroida	Beroidae	*Beroe gracilis*
				Beroe sp.
	Tentaculata	Cydippida	Pleurobrachiidae	*Pleurobrachia pileus*
		Lobata	Bolinopsidae	*Bolinopsis infundibulum*
				Ctenophore indet.
Echonodermata	Asteroidae			Asteroidae indet.
				Bipinnaria larvae
	Holothuroidea	Apodida	Synaptidae	*Protankyra* sp. (pentactula stage)

Phylum	Class	Order	Family	Taxon
	Ophiuroidea	Ophiurida	Ophiotrichidae	*Ophiothrix fragilis*
			Ophiuridae	*Ophiura ophiura*
				Ophiuroidea indet
				Echinopluteus
				Ophiopluteus larvae
				Echinodermata indet.
Foraminifera				Foraminifera
Hemichordata	Enteropneusta			Enteropneusta
Mollusca	Bivalvia	Mytiloida	Mytilidae	*Mytilus* sp.
				Bivalve veliger
	Gastropoda	Heterobranchia		Opisthobranch
		Littorinimorpha	Littorinidae	*Littorina littorea*
			Velutinidae	*Lamellaria* sp.
				Lamellaria perspicua
				Gastropod veliger
				Prosobranch veliger
Myzozoa	Dinophyceae	Noctilucales	Noctilucaceae	*Noctiluca* sp.
Nemertea				*Nemertea pilidium*
Phoronida				Actinotroch larvae
Rotifera				Rotifera
Tardigrada				Tardigrada indet.
				Other zooplankton egg
				Other zooplankton unknown

Table L.2 : In order of Phyla, the total average abundance m^{-3} of all zooplankton (species, genera, family or class) for monitoring years (2010 to 2014) inclusive.

Phylum	Zooplankton	2010	2011	2012	2014
Annelida	Aciculata trocophore		1.46		
	Aphroditoidea indet.		0.59	2.84	0.38
	Autolytinae indet.	0.03		0.06	
	Autolytus sp.	0.14			
	Eusyllis blomstrandi	0.02			
	Lagis sp.	0.80	0.08	6.73	0.19
	Lanice sp.	7.06	0.55	41.68	0.48
	Magelonidae	0.26	0.07	55.66	
	Malacoceros sp.				0.10
	Metatrocophore larvae	0.28	0.13	4.70	0.57
	Nectochaeta larvae	0.21		13.65	
	Pectinariidae	0.02	0.05		

Phylum	Zooplankton	2010	2011	2012	2014
	Pholoe baltica	0.02			
	Pholoe inaurata	0.05			
	Phyllodocidae indet.	0.03			
	Poecilochaetidae		0.03		
	Poecilochaetus sp.		0.01		0.10
	Polychaete indet.	3.55	0.15	1.98	1.52
	Polydora sp.	0.38			0.19
	Polynoidae			0.06	
	Pygospio elegans				0.57
	Sabellaria sp.	0.08	0.01		
	Sphaerodoridae		0.01		
	Spio sp.	0.31			
	Spionidae indet.	1.76	2.74	13.77	1.44
	Syllidae indet.	0.12	0.11	0.18	
	Syllis sp.	0.02			
	Terebellidae		0.01		
	Tomopteris helgolandica		0.01		
	Total Annelida	**15.17**	**6.02**	**141.30**	**5.53**
Arthropoda	Copepod eggs	0.41	0.17		
	Acartia clausi		3.84	5.21	24.46
	Acartia discaudata			0.03	
	Acartia spp.	61.25	12.42	0.93	
	Anomalocera patersoni			0.03	0.10
	Calanoida indet	4.64	0.58	1.65	1.14
	Calanus finmarchicus	0.07	0.11		0.19
	Calanus helgolandicus	0.20	0.15	0.06	0.57
	Calanus spp.	0.47	0.05		
	Centropages hamatus	50.65	34.95	186.34	39.79
	Centropages sp.	0.38	0.01		
	Diaixis hibernica		0.01		
	Eurytemora affinis		0.03		
	Isias clavipes	0.10	0.17	1.86	0.29
	Metridia lucens		0.01		
	Microcalanus sp.			0.03	
	Paracalanus parvus	47.15	39.21	9.01	5.05
	Parapontella brevicornis	0.02	0.08	0.12	

Phylum	Zooplankton	2010	2011	2012	2014
	Pseudo/Paracalanus #juv.	13.23	3.22	0.06	
	Pseudocalanus elongatus	8.40	29.14	34.53	52.89
	Temora longicornis	95.18	60.60	631.02	85.47
	Total Calanoida	**281.73**	**184.59**	**870.87**	**209.94**
	Corycaeus anglicus	0.92	2.62	0.09	
	Corycaeus sp.		0.05	0.03	
	Oncaea spp.	0.20			0.10
	Total Poecilostomatoida	**1.12**	**2.68**	**0.12**	**0.10**
	Benthic cyclopoida	0.69	0.41	1.77	0.19
	Oithona nana	0.02	0.11	0.09	
	Oithona plumifera	0.17			
	Oithona similis	0.39	1.23	0.60	
	Oithona sp.	0.03			
	Total Cyclopoida	**1.31**	**1.75**	**2.45**	**0.19**
	Alteutha depressa		0.05	0.12	
	Alteutha interrupta		0.03	0.03	0.10
	Alteutha sp.	0.12	0.44	0.78	0.67
	Alteuthella sp.		0.01		
	Benthic harpacticoid	0.58	0.09	0.69	
	Clytemnestra scutellata	0.05	0.03		
	Euterpina acutifrons	1.46	0.84	1.20	0.48
	Harpacticidae indet.	2.36	0.03	0.06	0.29
	Harpacticoida indet.	0.54	0.15	9.76	0.10
	Harpacticoida indet. (a)			0.12	
	Harpacticoida indet. (c)			0.09	
	Harpacticoida indet. (d)			3.02	
	Harpacticus sp.	0.24	0.03	0.48	
	Leptocaris sp.		0.03		
	Longipedia minor	0.05	0.05		0.57
	Longipedia scotti				0.19
	Longipedia sp.	0.02	0.99	4.58	0.57
	Microsetella rosea	0.02			
	Peltidiidae indet.	0.52	0.05	0.03	
	Sacodiscus sp.		0.01		
	Zaus sp.			0.03	

Phylum	Zooplankton	2010	2011	2012	2014
	Zausopsis sp.			0.03	
	Total Harpacticoida	**5.95**	**2.84**	**21.01**	**2.95**
	Cymbasoma sp.		0.01		
	Monstrilla grandis		0.03	0.03	
	Monstrilla longicornis	0.03	0.07	0.06	
	Monstrilla sp.		0.03		
	Total Monstrilloida	**0.03**	**0.13**	**0.09**	
	Total Copepoda	**290.14**	**191.99**	**894.54**	**213.19**
	Acanthephyra sp.		0.01		
	Amphilochidae	0.02	0.04	0.06	
	Amphipoda indet.			0.03	0.19
	Anomura indet.	0.07	0.08	0.24	
	Aoridae		0.01		
	Apseudidae indet.		0.01		
	Arachnid indet.	0.08	0.01	0.06	
	Atelecyclus sp.		0.01	0.06	
	Athanas nitiscens		0.01		
	Bosmina sp.		0.01		
	Brachynotus sexdentatus		0.03		
	Brachyura indet.	1.82	1.19	0.90	2.29
	Calliophidae				0.10
	Cancer sp.	0.15	0.20	0.15	
	Caprella sp.	0.02			
	Caprellidae indet.	0.05	0.04	0.24	
	Carcinus sp.		0.04	1.05	0.58
	Caridean indet.	0.36	0.87	0.24	1.14
	Cinetorhynchus sp.		0.04	0.03	
	Corystes cassivelaunus			0.03	
	Crangon allmanni	0.03		0.03	0.10
	Crangon crangon	0.03			
	Crustacean egg	0.09			
	Cumacea indet	0.14	0.15	0.42	0.38
	Cyprid larvae indet.	10.33	1.87	19.21	4.76
	Decapoda indet.	0.14	0.12		
	Ebalia sp.		0.01	0.03	0.29
	Epicarid isopod		0.01		
	Eualus sp.		0.01		
	Euphausiidae		0.01	0.03	0.19
	Eurynome sp.			0.03	

Phylum	Zooplankton	2010	2011	2012	2014
	Evadne normanni	0.21	1.15	0.21	
	Evadne sp.	0.10	0.07	2.39	
	Evadne spinifera		0.03		
	Galathea sp.			0.09	
	Gammaridea indet.	0.32	0.24	0.15	
	Gastrosaccus sp.	0.02			
	Geryonidae indet.	0.24			
	Gnathiidae		0.07	0.06	
	Halacaridae indet.	0.03	0.03	0.06	0.10
	Hippolyte sp.		0.01		
	Homarus gammarus			0.03	
	Hyas sp.			0.03	
	Idotea	0.07	0.01		
	Isaeidae				0.10
	Ischyroceridae	0.02			
	Isopoda indet.	0.16	0.15	0.09	
	Macropodia sp.		0.01		
	Monodaeus couchii		0.03		
	Munida sp.			0.03	
	Munnidae		0.01	0.03	
	Mysidae indet.		0.01		
	Nanocassiope melanodactyla		0.07		
	Nepinnotheres pinnotheres	0.05			
	Ostracod		0.07	0.27	
	Palaemon sp.			0.03	
	Pandalina sp.		0.01		
	Pandalina brevirostris			0.24	
	Parthenope indet.	0.02			
	Pasiphaea sp.	0.02	0.03	0.03	
	Phtisica marina	0.27	0.01		
	Pilumnus sp.	0.02	0.20		
	Pinnotheres pissum		0.03		
	Pirimela denticulata		0.01	0.12	0.76
	Pisidia longicornis	0.60	0.92	0.15	0.10
	Podocopida			0.06	0.10
	Podon intermedius	0.02	0.17	0.06	
	Podon leukart	1.37	0.62	1.62	
	Podon spp.	0.32	0.09	0.03	0.10

Phylum	Zooplankton	2010	2011	2012	2014
	Porcellana platycheles	0.71			0.10
	Porcellanidae indet.	0.41			
	Portumnus latipes			0.06	
	Portumnus sp.		0.04	0.06	
	Thalassinidae indet.	0.07			
	Thia scutellata			0.09	
	Thoracica nauplius	28.45	19.24	161.26	86.21
	Thoralus sp.		0.01		
	Uca tangeri	0.03	0.01		
	Xantho sp.		0.03		
Total Arthropoda (Excluding Copepoda)		**46.91**	**28.21**	**190.08**	**97.56**
Brachiopoda	Brachiopoda	0.21	0.04		
	Lingulacea larvae	0.16			
Total Brachiopoda		**0.37**	**0.04**		
Total Bryozoa		**0.70**	**3.77**	**19.24**	**20.66**
Chaetognatha	Chaetognatha indet.		0.01	0.03	
	Parasagitta elegans	0.07	0.25	0.09	0.67
	Parasagitta setosa	4.84	2.64	0.66	1.05
	Parasagitta sp.	3.02	0.35	0.15	0.10
	Spadella cephaloptera			0.03	
Total Chaetognatha		**7.93**	**3.25**	**0.96**	**1.81**
Chordata	*Ammodytes lancea*	0.04			
	Ammodytes marinus		0.03		
	Ammodytidae			0.18	
	Appendicularia	6.91	10.99	103.21	17.99
	Arnoglossus laterna	0.02			
	Ascidian tadpole	0.02		0.09	
	Chirolophis askanii			0.03	
	Clupea harengus			0.03	
	Crenilabrus melops		0.03		
	Fish indet.	0.03	0.12	0.24	
	Fish egg indet.	0.25	0.16	0.99	0.77
	Gobiidae				0.19
	Limanda limanda				0.10
	Merlangius merlangus			0.03	
	Oikopleura larvae	0.80	0.01		
	Platichthys flesus			0.03	
	Pomatoschistus		0.01		

Phylum	Zooplankton	2010	2011	2012	2014
	minutus				
	Solea solea			0.03	
	Soleidae			0.09	
Total Chordata		**8.08**	**11.35**	**104.95**	**19.04**
Cnidaria	Actinula larva		0.03		
	Amphinema sp.		0.04		
	Anthoathecata	0.09	0.63	0.06	0.10
	Anthozoa indet.	0.07	0.05	0.69	
	Aurelia aurita			0.39	
	Clytia hemisphaerica	2.03	1.04	0.15	0.10
	Cnidaria indet.	0.06			
	Coryne prolifera				0.10
	Coryne sp.		0.04	0.15	
	Corynidae		0.04	0.09	
	Cosmetira pilosella				0.10
	Diphyinae				0.10
	Euphysa sp.		0.12		
	Gossea corynetes		0.04		
	Hybocodon prolifer		0.04		
	Hydractinia sp.			0.06	
	Hydrozoa indet.	0.17	0.28	0.15	
	Leptothecata	0.82	1.67	1.56	2.86
	Liriope tetraphylla	0.03		0.30	
	Lizzia blondina	0.06			
	Lovenella sp.			0.03	
	Mitrocomella brownei		0.01		
	Modeeria rotunda				0.10
	Obelia sp.	0.03	0.09	0.03	0.19
	Phialella quadrata			0.06	0.48
	Phialella sp.		0.98	0.12	
	Sarsia spp.	0.05	0.03	0.30	
	Sarsia tubulosa	0.04			
	Scyphozoa indet.		0.01	0.06	0.48
	Semaeostomeae		0.08	0.03	
	Stauridiosarsia ophiogaster				0.10
	Turritopsis nutricula		0.01		
	Zanclea sp.		0.04		
Total Cnidaria		**3.45**	**5.29**	**4.22**	**4.67**
Ctenophora	*Beroe gracilis*				0.19

Phylum	Zooplankton	2010	2011	2012	2014
	Beroe sp.		0.01	0.03	0.10
	Bolinopsis infudibulum		0.04		
	Ctenophore indet.	0.17	0.16		
	Pleurobrachia pileus		0.33	1.11	0.48
Total Ctenophora		**0.17**	**0.55**	**1.14**	**0.76**
Echinodermata	Asteroidae indet.	0.10	0.04	0.03	
	Bipinnaria larvae	0.27			
	Echinodermata indet.		0.03		
	Echinopluteus	0.05	0.01		0.67
	Ophiopluteus larvae	0.42	0.59	0.21	0.19
	Ophiothrix fragilis	0.09		0.03	
	Ophiura ophiura	0.13			
	Ophiuroidea indet	0.59	0.13	0.03	0.10
	Protankyra sp. (pentactula stage)				0.19
Total Echinodermata		**1.65**	**0.80**	**0.30**	**1.14**
Total Other Egg		**1.17**	**1.11**	**0.87**	**1.71**
Total Foraminifera			**0.24**	**1.11**	**0.19**
Total Hemichordata			**0.01**	**0.03**	
Mollusca	Bivalve veliger		0.98	0.84	0.19
	Gastropod veliger	1.27	0.55	1.50	
	Lamellaria sp.		0.01	0.09	
	Lamellaria perspicua		0.11	0.12	0.10
	Littorina littorea	0.70	1.82	12.93	4.48
	Mytilus sp.	0.05			
	Opisthobranch			0.03	
	Prosobranch veliger	0.36	0.11	0.12	1.82
Total Mollusca		**2.38**	**3.57**	**15.62**	**6.59**
Total Myzozoa		**91.64**	**73.55**	**156.21**	**9.42**
Total Nemertea		**0.03**			
Total Phoronida		**0.04**			
Total Rotifera			**0.01**		
Total Tardigrada				**0.03**	
Total Other Zooplankton		**0.24**	**0.24**	**0.45**	**0.57**

Table L.3 : Output of two-way SIMPER analysis displaying contribution of zooplankton taxa to the dissimilarity between monitoring years across all seasons. Only taxa cumulatively contributing to 50% of dissimilarity are displayed.

Years 2010 & 2011				
Average dissimilarity = 59.20	**2010**	**2011**	**Contribution (%)**	**Cumulative (%)**
Taxa	**Average abundance (square root)**	**Average abundance (square root)**		
Noctiluca indet.	4.56	4.24	10.07	10.07
Acartia spp.	6.05	2.18	7.66	17.73
Temora longicornis	8.34	6.46	6.59	24.32
Paracalanus parvus	5.38	4.84	5.16	29.48
Centropages hamatus	6.21	4.7	4.92	34.4
Pseudo/Paracalanus #juv.	2.43	0.71	3.94	38.34
Pseudocalanus elongatus	2.41	4.46	3.19	41.54
Appendicularia	1.84	2.65	3.11	44.64
Acartia clausi	0	1	2.72	47.37
Thoracica nauplius	2.58	2.71	2.09	49.46
Calanoida indet.	1.34	0.34	1.86	51.32
Years 2010 & 2012				
Average dissimilarity = 62.26	**2010**	**2012**	**Contribution (%)**	**Cumulative (%)**
Taxa	**Average abundance (square root)**	**Average abundance (square root)**		
Noctiluca indet.	4.56	3.48	13.01	13.01
Temora longicornis	8.34	14.72	9.45	22.46
Centropages hamatus	6.21	7.81	5.7	28.16
Acartia spp.	6.05	0.22	5.16	33.32
Thoracica nauplius	2.58	9.36	4.02	37.34
Appendicularia	1.84	5.23	3.69	41.03
Acartia clausi	0	1.17	3.18	44.21
Paracalanus parvus	5.38	2.19	2.98	47.19
Pseudocalanus elongatus	2.41	4.86	2.91	50.1
Years 2011 & 2012				
Average dissimilarity = 62.87	**2011**	**2012**	**Contribution (%)**	**Cumulative (%)**
Taxa	**Average abundance (square root)**	**Average abundance (square root)**		
Temora longicornis	6.46	14.72	10.38	10.38
Centropages hamatus	4.7	7.81	7.78	18.16
Thoracica nauplius	2.71	9.36	7.34	25.5

Appendicularia	2.65	5.23	4.88	30.39
Pseudocalanus elongatus	4.46	4.86	4.49	34.88
Noctiluca indet.	4.24	3.48	3.81	38.69
Paracalanus parvus	4.84	2.19	3.76	42.45
Acartia spp.	2.18	0.22	3.58	46.03
Littorina littorea	0.68	2.5	3.48	49.5
Spionidae indet.	1.04	2.85	2.7	52.2
Years 2010 & 2014				
Average dissimilarity = 66.86	**2010**	**2014**	**Contribution (%)**	**Cumulative (%)**
Taxa	**Average abundance (square root)**	**Average abundance (square root)**		
Noctiluca indet.	4.56	1.38	10.62	10.62
Acartia spp.	6.05	0	5.92	16.54
Thoracica nauplius	2.58	7.33	5.55	22.09
Temora longicornis	8.34	7.6	5.53	27.63
Acartia clausi	0	3.62	5.39	33.02
Pseudocalanus elongatus	2.41	6.65	5.31	38.33
Centropages hamatus	6.21	4.68	4.64	42.97
Cyprid larvae indet.	1.44	1.62	3.89	46.86
Bryozoa indet. larvae	0.14	3.9	3.49	50.35
Years 2011 & 2014				
Average dissimilarity = 57.21	**2011**	**2014**	**Contribution (%)**	**Cumulative (%)**
Taxa	**Average abundance (square root)**	**Average abundance (square root)**		
Temora longicornis	6.46	7.6	8.78	8.78
Thoracica nauplius	2.71	7.33	7.22	16
Centropages hamatus	4.7	4.68	7.02	23.01
Pseudocalanus elongatus	4.46	6.65	6.07	29.08
Acartia spp.	2.18	0	5.08	34.15
Appendicularia	2.65	3.24	4.53	38.68
Acartia clausi	1	3.62	4.15	42.83
Bryozoa indet. larvae	1.07	3.9	3.97	46.8
Noctiluca indet.	4.24	1.38	3.79	50.59

Years 2012 & 2014				
Average dissimilarity = 64.01	2012	2014	Contribution (%)	Cumulative (%)
Taxa	Average abundance (square root)	Average abundance (square root)		
Temora longicornis	14.72	7.6	15.01	15.01
Thoracica nauplius	9.36	7.33	10.99	26
Centropages hamatus	7.81	4.68	7.81	33.81
Appendicularia	5.23	3.24	6.01	39.82
Magelonidae	3.45	0	3.93	43.75
Lanice sp.	3.21	0.29	3.78	47.53
Pseudocalanus elongatus	4.86	6.65	3.67	51.2

Table L.4 : Output of one-way ANOSIM analysis detailing pairwise comparisons for all zooplankton taxa between months. Highlighted rows indicate considerable overlap between communities (R value <0.250).

Groups	R Statistic	Significance Level %
May, June	0.152	0.1
May, July	0.311	0.1
May, August	0.415	0.1
May, September	0.686	0.1
May, October	0.855	0.1
May, November	0.909	0.1
May, December	0.585	0.1
May, January	0.764	0.1
May, February	0.869	0.1
May, March	0.654	0.1
May, April	0.2	0.1
June, July	0.123	0.3
June, August	0.238	0.1
June, September	0.691	0.1
June, October	0.866	0.1
June, November	0.914	0.1
June, December	0.665	0.1
June, January	0.824	0.1
June, February	0.953	0.1
June, March	0.863	0.1
June, April	0.587	0.1
July, August	0.082	2.5
July, September	0.587	0.1
July, October	0.75	0.1
July, November	0.709	0.1

Groups	R Statistic	Significance Level %
July, December	0.356	0.1
July, January	0.75	0.1
July, February	0.913	0.1
July, March	0.86	0.1
July, April	0.68	0.1
August, September	0.343	0.1
August, October	0.533	0.1
August, November	0.511	0.1
August, December	0.202	1.1
August, January	0.6	0.1
August, February	0.916	0.1
August, March	0.877	0.1
August, April	0.675	0.1
September, October	0.082	1.2
September, November	0.234	0.1
September, December	0.154	3.9
September, January	0.506	0.1
September, February	0.95	0.1
September, March	0.938	0.1
September, April	0.801	0.1
October, November	0.005	38.9
October, December	0.251	0.1
October, January	0.456	0.1
October, February	0.915	0.1
October, March	0.942	0.1
October, April	0.879	0.1
November, December	0.23	1.5
November, January	0.326	0.2
November, February	0.907	0.1
November, March	0.94	0.1
November, April	0.889	0.1
December, January	0.189	3.7
December, February	0.868	0.1
December, March	0.894	0.1
December, April	0.732	0.1
January, February	0.623	0.1
January, March	0.824	0.1
January, April	0.758	0.1
February, March	0.57	0.1
February, April	0.762	0.1

Groups	R Statistic	Significance Level %
March, April	0.429	0.1

Table L.5 : Output of two-way crossed SIMPER analysis displaying contribution of zooplankton taxa to the dissimilarity between seasons across all years. Only taxa cumulatively contributing to 50% of dissimilarity are displayed.

Groups Spring & Summer				
Average dissimilarity = 66.76	Spring	Summer	Contribution (%)	Cumulative (%)
Taxa	Average abundance (square root)	Average abundance (square root)		
Noctiluca indet	2.92	10.56	15.84	15.84
Thoracica nauplius	11.47	2.11	8.98	24.81
Temora longicornis	14.84	9.48	6.45	31.26
Centropages hamatus	8.23	7.18	5.43	36.7
Pseudocalanus elongatus	5.97	2.17	5.12	41.81
Acartia spp.	2.02	4.98	4.39	46.2
Appendicularia	5.75	1.95	3.47	49.68
Cyprid larvae indet.	3.86	0.57	3.39	53.06

Groups Spring & Autumn				
Average dissimilarity = 71.79	Spring	Autumn	Contribution (%)	Cumulative (%)
Taxa	Average abundance (square root)	Average abundance (square root)		
Thoracica nauplius	11.47	0.19	11.16	11.16
Paracalanus parvus	1.66	8.73	8.08	19.24
Temora longicornis	14.84	5.84	6.74	25.98
Centropages hamatus	8.23	3.76	5.53	31.5
Noctiluca indet	2.92	0.7	4.95	36.45
Pseudocalanus elongatus	5.97	3.39	4.37	40.82
Cyprid larvae indet.	3.86	0.06	3.82	44.65
Acartia spp.	2.02	1.99	3.79	48.43
Appendicularia	5.75	2.2	3.44	51.88

Groups Summer & Autumn				
Average dissimilarity = 65.81	**Summer**	**Autumn**	**Contribution (%)**	**Cumulative (%)**
Taxa	**Average abundance (square root)**	**Average abundance (square root)**		
Noctiluca indet	10.56	0.7	12.74	12.74
Paracalanus parvus	3.26	8.73	8.84	21.57
Temora longicornis	9.48	5.84	7.29	28.86
Centropages hamatus	7.18	3.76	5.66	34.52
Acartia spp.	4.98	1.99	5.47	39.99
Parasagitta setosa	0.32	2.58	3.42	43.41
Pseudocalanus elongatus	2.17	3.39	3.32	46.73
Pseudo/Paracalanus #juv.	0.54	1.96	2.7	49.42
Appendicularia	1.95	2.2	2.68	52.11
Groups Spring & Winter				
Average dissimilarity = 68.67	**Spring**	**Winter**	**Contribution (%)**	**Cumulative (%)**
Taxa	**Average abundance (square root)**	**Average abundance (square root)**		
Thoracica nauplius	11.47	1.97	12.94	12.94
Temora longicornis	14.84	1.97	12.7	25.64
Centropages hamatus	8.23	2.35	7.55	33.19
Appendicularia	5.75	1.37	4.94	38.13
Pseudocalanus elongatus	5.97	5.14	4.56	42.69
Bryozoa indet. larvae	3.85	0.81	4.22	46.91
Cyprid larvae indet.	3.86	0.03	3.8	50.71
Groups Summer & Winter				
Average dissimilarity = 72.74	**Summer**	**Winter**	**Contribution (%)**	**Cumulative (%)**
Taxa	**Average abundance (square root)**	**Average abundance (square root)**		
Noctiluca indet	10.56	0.4	20.64	20.64
Temora longicornis	9.48	1.97	7.67	28.31
Pseudocalanus elongatus	2.17	5.14	6.09	34.4
Centropages hamatus	7.18	2.35	5.7	40.09
Paracalanus parvus	3.26	3.78	3.68	43.78
Acartia spp.	4.98	1.11	3.54	47.32
Pseudo/Paracalanus #juv.	0.54	1.57	3.21	50.53

Groups Autumn & Winter				
Average dissimilarity = 65.04	Autumn	Winter	Contribution (%)	Cumulative (%)
Taxa	Average abundance (square root)	Average abundance (square root)		
Paracalanus parvus	8.73	3.78	9.51	9.51
Temora longicornis	5.84	1.97	7.58	17.09
Centropages hamatus	3.76	2.35	6.42	23.51
Pseudocalanus elongatus	3.39	5.14	5.8	29.32
Acartia clausi	1.48	0.08	4.83	34.15
Pseudo/Paracalanus #juv.	1.96	1.57	4.38	38.53
Corycaeus anglicus	1.71	0.14	4.34	42.87
Parasagitta setosa	2.58	0.47	3.7	46.57
Appendicularia	2.2	1.37	3.27	49.84
Thoracica nauplius	0.19	1.97	3.25	53.09

Table L.6 : Output of one-way ANOSIM analysis detailing pairwise comparisons for copepod taxa between months. Highlighted rows indicate either insignificant results (significance level < 1%) or where R statistic is <0.450.

Groups	R Statistic	Significance Level %
May, June	0.019	18.1
May, July	0.105	0.5
May, August	0.204	0.1
May, September	0.494	0.1
May, October	0.698	0.1
May, November	0.778	0.1
May, December	0.29	0.2
May, January	0.706	0.1
May, February	0.915	0.1
May, March	0.592	0.1
May, April	0.163	0.1
June, July	0.061	4.6
June, August	0.169	0.2
June, September	0.403	0.1
June, October	0.659	0.1
June, November	0.793	0.1
June, December	0.305	0.2
June, January	0.726	0.1
June, February	0.933	0.1
June, March	0.623	0.1
June, April	0.283	0.1
July, August	0.021	21.5

Groups	R Statistic	Significance Level %
July, September	0.382	0.1
July, October	0.56	0.1
July, November	0.596	0.1
July, December	0.166	4.1
July, January	0.666	0.1
July, February	0.858	0.1
July, March	0.529	0.1
July, April	0.311	0.1
August, September	0.208	0.1
August, October	0.373	0.1
August, November	0.392	0.1
August, December	0.03	29.7
August, January	0.545	0.1
August, February	0.837	0.1
August, March	0.543	0.1
August, April	0.32	0.1
September, October	0.074	3.3
September, November	0.173	0.2
September, December	0.125	6.8
September, January	0.498	0.1
September, February	0.861	0.1
September, March	0.58	0.1
September, April	0.474	0.1
October, November	-0.056	93.7
October, December	0.213	0.8
October, January	0.416	0.1
October, February	0.732	0.1
October, March	0.529	0.1
October, April	0.61	0.1
November, December	0.288	0.4
November, January	0.399	0.1
November, February	0.726	0.1
November, March	0.512	0.1
November, April	0.629	0.1
December, January	0.241	1.3
December, February	0.682	0.1
December, March	0.299	0.4
December, April	0.322	0.2
January, February	0.307	0.1
January, March	0.351	0.1

Groups	R Statistic	Significance Level %
January, April	0.505	0.1
February, March	0.286	0.1
February, April	0.755	0.1
March, April	0.459	0.1

Table L.7 : Output of two-way SIMPER analysis displaying contribution of copepod species to the dissimilarity between seasons across all years. Only taxa cumulatively contributing to 50% of dissimilarity are displayed.

Groups Spring & Summer				
Average dissimilarity = 51.25	**Spring**	**Summer**	**Contribution (%)**	**Cumulative (%)**
Taxa	**Average abundance (square root)**	**Average abundance (square root)**		
Temora longicornis	14.84	9.48	18.66	18.66
Centropages hamatus	8.23	7.18	15.81	34.47
Pseudocalanus elongatus	5.97	2.17	15.05	49.51
Acartia spp.	2.02	4.98	12.35	61.87

Groups Spring & Autumn				
Average dissimilarity = 58.32	**Spring**	**Autumn**	**Contribution (%)**	**Cumulative (%)**
Taxa	**Average abundance (square root)**	**Average abundance (square root)**		
Paracalanus parvus	1.66	8.73	19.06	19.06
Temora longicornis	14.84	5.84	15.82	34.88
Centropages hamatus	8.23	3.76	12.86	47.74
Pseudocalanus elongatus	5.97	3.39	10.06	57.8
Groups Summer & Autumn				
Average dissimilarity = 53.36	**Summer**	**Autumn**	**Contribution (%)**	**Cumulative (%)**
Taxa	**Average abundance (square root)**	**Average abundance (square root)**		
Paracalanus parvus	3.26	8.73	19.1	19.1
Temora longicornis	9.48	5.84	14.92	34.01
Centropages hamatus	7.18	3.76	11.89	45.9
Acartia spp.	4.98	1.99	10.51	56.41

Groups Spring & Winter				
Average dissimilarity = 58.85	Spring	Winter	Contribution (%)	Cumulative (%)
Taxa	Average abundance (square root)	Average abundance (square root)		
Temora longicornis	14.84	1.97	31.87	31.87
Centropages hamatus	8.23	2.35	18.09	49.95
Pseudocalanus elongatus	5.97	5.14	11.04	60.99
Groups Summer & Winter				
Average dissimilarity = 61.28	**Summer**	**Winter**	**Contribution (%)**	**Cumulative (%)**
Taxa	**Average abundance (square root)**	**Average abundance (square root)**		
Temora longicornis	9.48	1.97	19.25	19.25
Pseudocalanus elongatus	2.17	5.14	15.17	34.41
Centropages hamatus	7.18	2.35	14.44	48.85
Paracalanus parvus	3.26	3.78	8.96	57.81
Groups Autumn & Winter				
Average dissimilarity = 56.53	**Autumn**	**Winter**	**Contribution (%)**	**Cumulative (%)**
Taxa	**Average abundance (square root)**	**Average abundance (square root)**		
Paracalanus parvus	8.73	3.78	17.3	17.3
Temora longicornis	5.84	1.97	13.7	31
Centropages hamatus	3.76	2.35	11.28	42.28
Pseudocalanus elongatus	3.39	5.14	10.48	52.76