Pembroke Power Station Non-Technical Summary 2023

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RWE Generation UK plc

Pembroke Environmental Monitoring
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1. Introduction

1.1 Overview

RWE Generation UK plc (RWE) has commissioned a full marine ecological survey programme in the vicinity of the combined cycle gas turbine (CCGT) Pembroke Power Station on the Milford Haven Waterway (Milford Haven). This has included fish, plankton, seabed-dwelling marine flora (plants) and fauna (animals) as well as water quality surveys repeated at fixed intervals. Surveys have been undertaken since 2006, for varying periods. The programme was agreed at the outset with the Environment Agency Wales (now Natural Resources Wales (NRW)) in the form of the Environmental Permit Condition PO4a.

This document is the non-technical summary of the marine environmental monitoring annual reports from 2006 to date. Technical details for each element of the monitoring programme, data analyses and detailed assessments are given within the annual reports which are provided to NRW under the agreed monitoring programme required by Condition PO4a.

1.2 Pembroke Power Station

In 2012, RWE completed construction of a new gas fired CCGT power station on the site of a previous oil-fired power station at West Pennar, Pembroke, adjacent to Pennar Gut at the mouth of the Pembroke River. A CCGT uses a turbine driven by steam raised from the gas turbine exhaust gas to extract more energy from the fuel than would be possible by using the gas turbine alone. This increases the overall efficiency of the conversion process and, therefore, results in less resource use and atmospheric emissions per unit of generation. It is necessary to cool the steam after it leaves the steam turbine so that it can be reused within the process. Pembroke Power Station uses a once through cooling system, abstracting cooling water (CW) from Pennar Gut and returning it via an outlet across Pwllcrochan Flats on the southern shore of Milford Haven. The use of this cooling increases the efficiency of the plant, making Pembroke Power Station one of the most efficient CCGTs in Europe. There are five CCGT units at the Pembroke Power Station.

The CW system is state of the art and has many design features aimed at managing the impact of the system in operation. These include an intake located in an engineered intake channel away from the main channel, a large intake area to achieve a low approach velocity at all tidal states, an Acoustic Fish Deterrent (AFD) incorporating strobe lighting, and a fish friendly recovery and return system. The station also has a low through plant temperature rise and low Total Residual Oxidant (TRO) concentration in the returned cooling water compared to peer group plants, leading to reduced exposure of marine life to TRO in the discharge. All these design features combine to minimise impact on the waterway.

1.3 Monitoring aims and objectives

The monitoring can be split into three distinct periods:

- Pre-commissioning: between 2006 and January 2012.
- Commissioning: between January 2012 and September 2012 (a gradual increase in heat release and CW flow during this period); and
- Operational: between September 2012 to the present date. Some or all of the five CCGT units that make up the plant may '2 shift' (i.e., operating between ~0600 hrs and ~2300 hrs only, to meet peak demand), resulting in a reduced abstraction and heat load to the Haven when compared to the maximum permitted level.

The overall aim of monitoring prior to commissioning of the station was to gather marine ecology and water quality information for the area. From September 2012 the purpose of monitoring has been to determine if any changes in the water quality and marine ecological communities of Milford Haven have occurred and to inform an assessment of whether any such change could have a causal link to the operation of the station. Power station operational influences are principally those due to abstraction and return of cooling water (which includes emission of heat and chemicals arising from chlorination).

The programme required by Environmental Permit Condition PO4a has a clear scope which has been approved by the regulator. The monitoring programme focuses in the area within a few kilometers of the power station intake and outfall. This is because any influences or changes caused by the intake or outfall would be more easily identifiable within this area and are less likely as distance increases beyond this area.

1.4 Study area

Milford Haven, located in southwest Wales, is a component of the Pembrokeshire Marine Special Area of Conservation (SAC). The area has a diverse array of marine habitats including estuaries, large shallow inlets and bays, and reefs.

Milford Haven is the largest ria-estuary (flooded valley) complex in the UK. The marine communities throughout Milford Haven are highly diverse which are associated with the wide range of environmental conditions, particularly the seabed substrata and salinity gradients. The wide range of intertidal habitats supports a variety of faunal communities which, in turn, support populations of over-wintering birds. The intertidal and subtidal sedimentary habitats support abundant faunal communities dominated by worms and bivalves. The area also supports a diverse array of sensitive habitats including a maerl bed (calcified algae), small rocky reefs, subtidal and intertidal mudflats, as well as seagrass beds which are reflective of the high level of water quality within the Haven.

The Pembrokeshire Marine SAC supports a diverse fish assemblage, which includes four taxa listed as secondary qualifying species in the SAC citation: Allis and Twaite shad, sea and river lamprey. Milford Haven is also an important fish nursery habitat, especially for the European seabass and a local race of herring, the latter spawning in spring in the waters of the Daugleddau (the confluence of the East and West Cleddau). Two other areas of the Haven are also designated as seabass nursery areas - one of which is adjacent to the power station site. The Haven also sees an annual spawning run of salmon and sea trout into the freshwater catchments.

The main freshwater input to the Haven comes from the East and West Cleddau Rivers, although the Cresswell, Carew and Pembroke Rivers also provide freshwater input along with numerous small streams.

Industrial use of Milford Haven is extensive and long-established including use for shipping, oil refining, military, and power generation. Other inputs related to human activity include domestic and agricultural effluents which contribute to a considerable nutrient input to the waterway.

1.5 Monitoring elements

The following elements of the marine environment have been monitored at different frequencies since Pembroke Power Station began CW abstraction at full operation in September 2012. Most of these elements have also been monitored pre-commissioning since 2009; with some monitored as early as 2006. Monitoring includes non-mobile biota (which respond to changing conditions occurring at a particular location), mobile biota (which respond to changing conditions over their range, which itself may change in response to conditions) and habitats (areas with particular species interest, the extent and condition of which may change), as follows:

- Bathymetry (mapping of the seabed contours);
- Marine water quality (physical and chemical properties of the water);
- Haven temperature monitoring;
- Chlorination By-Products (CBPs) (substances that form as a result of dosing chemicals to control biological growth in the CW system) in water and biota;
- Phytoplankton (single-celled algae living in the water column);
- Zooplankton (microscopic animals living in the water column);
- Ichthyoplankton (fish eggs and larvae);
- Intertidal (between the high and low tide margins) and subtidal (below the low tide margin) fish;
- Seagrass;
- Macroalgae (seaweed);
- Intertidal benthic ecology (seabed-dwelling biota between the high- and low-tide margins);
- Subtidal sediment quality and benthic ecology (biota living in or on sediments below the low tide margin);
- Subtidal epifauna (biota living on hard substrates); and
- Entrapment (the combination of biota retained on the CW intake screens and biota that pass through the screens into the CW system).

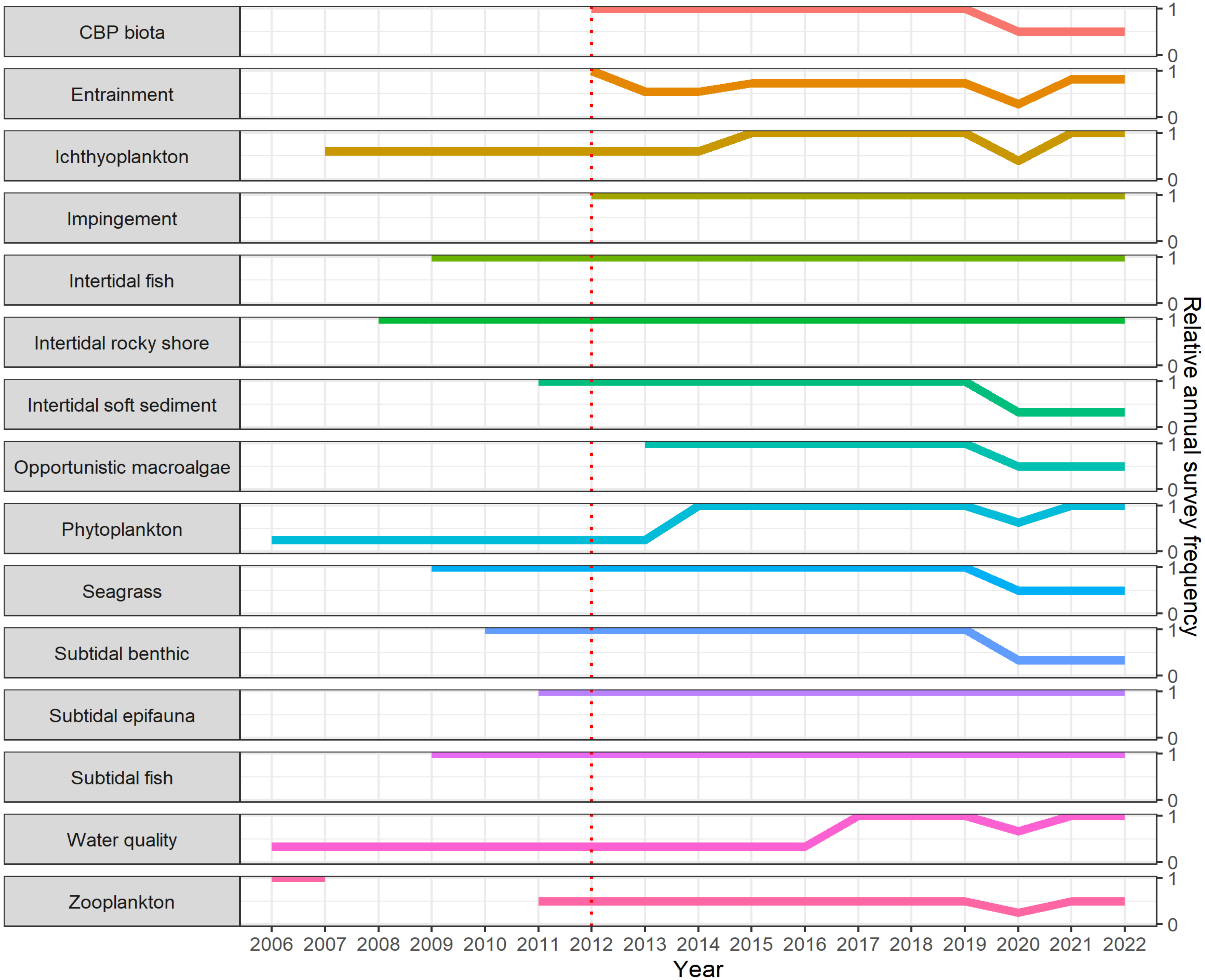


Figure 1-1. Relative annual frequency of each survey conducted as part of the Pembroke marine environmental monitoring programme. Frequencies are relative to the maximum number of instances each survey type was conducted within a year. Red dotted line indicates the start of full operation of Pembroke Power Station in 2012.

1.6 Future monitoring

A revised monitoring programme has been approved by NRW for 2023 – 2025. Historically, changes to the programme have been approved by NRW in response to changing circumstances and monitoring findings, to ensure the work remains well-focused.

1.7 Overall conclusion

The operation of the power station has been shown to locally influence temperature in the Milford Haven Waterway. The scale and range of this influence is in line with that assessed within the original environmental assessment, and what would be expected under natural variation and would not be expected to lead to changes of ecological or conservational significance at the survey sites.

The entrapment of fish resulting from operation of the power station results in a small pressure on the fish community using Milford Haven Waterway. It is also shown to be small compared with other non-power station related pressures including natural predation by seabirds, otters and seals, as well as commercial fishing.

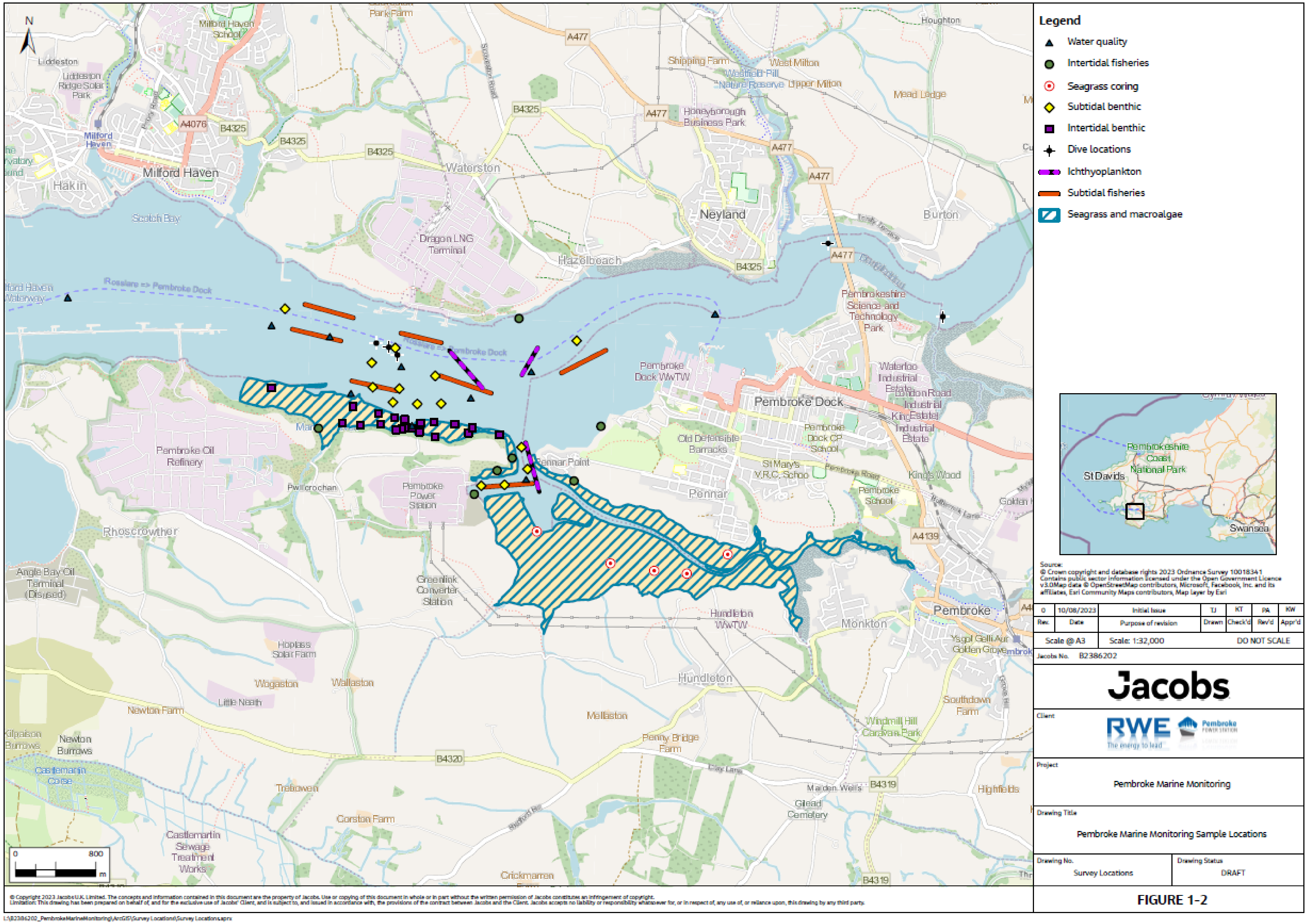
As a highly dynamic environment, Milford Haven experiences continual natural changes in its physical and ecological aspects. To date, the monitoring programme has shown that there are some year-to-year differences in the physico-chemical and biological parameters examined for several of the elements considered. These differences are considered to reflect the natural variation typical of dynamic environments, populations and communities, such as those in Milford Haven. Such differences are not considered to be of a scale, or range, of ecological or conservational significance.

2. Summary of conclusions from the individual survey elements to 2022. Further details provided in Appendix A

Monitoring	Conclusion
Bathymetry	There is no evidence that the power station operation is having a detrimental impact on the seabed levels around the intake and outfall areas. There have been some changes in seabed levels but these are in line with what was expected and not of ecological significance.
Marine water quality	There is no evidence that power station operation is having a detectable impact on the physico-chemical and other water quality parameters at the monitoring locations. Some small differences in physico-chemical parameters observed between years are related to natural environmental processes (seasonal and inter-annual variations) rather than a direct effect of the power station.
Milford Haven water temperature	Natural processes, including the seasonally changing balance of net radiation and interaction with the atmosphere, tidal forcing, meteorology and fluvial flow are the dominant factors influencing the observed temperature changes on all timescales. At the temperature monitoring network locations the power station operation is generally a modest perturbation on the natural temperature variation. The results of the hydrodynamic climate modelling that includes climate change predictions required by the permit show limited impacts on the size of mixing zones and hence no necessity to change the future operation of the station.
CBPs – water and biota	There is no evidence of detrimental impacts of CBPs on the Haven communities or any influence of the power station operation. The CBPs concentrations in both the watercourse and the tissue of affected organisms are below the limit of detection in faunal samples. It is considered that any observed changes in the condition of the organisms monitored is related to seasonal variability, in addition to other environmental factors.
Phytoplankton	There is no evidence that power station operation is having an ecologically significant impact on phytoplankton populations. Effects on phytoplankton from thermal, chemical and mechanical stress resulting from power station operation are negligible. The observed annual variability in the magnitudes and timings of peak abundance is considered to be a result of variability in riverine discharge and turbidity, influencing plankton residence times and light availability within the estuary.
Zooplankton	There is no evidence that power station operation is having a detectable impact on zooplankton populations. Community dynamics and fluctuations in abundance remain consistent with expected seasonal temperature and salinity variations within an estuarine environment.
Ichthyoplankton	There is no evidence that power station operation is having a detectable impact on ichthyoplankton communities. High variability in ichthyoplankton abundance was evident during both pre- and post-operation; however, the overall annual patterns observed and species composition have remained similar.
Intertidal and subtidal fish	There is no evidence that power station operation is having a detectable impact on fish populations with the Haven. The differences observed in fish abundance and community structure over the monitoring period, remain in line with expected variation and are of a magnitude and nature which is not significant from an ecological and conservational point of view. The observed variability in fish community data is the result of high mobility, seasonal behaviour and complex life histories, and would be expected to display natural variation between seasons and years.
Seagrass	There is no evidence that power station operation is having any measurable impact on environmental quality in relation to the seagrass beds and associated intertidal habitats and faunal communities in Pennar Gut. A steady increase in the extent of the monitored seagrass beds has been noted.
Macroalgae	There is no evidence that power station operation is having an impact on macroalgal growth. The factors supporting opportunistic macroalgal growth are likely to be driven by nutrient input, availability of light, suitable habitat, and, to a lesser extent, minor increases in the water temperature due to the CW returned to the Haven.
Intertidal benthic ecology	There is no evidence that power station operation is having a detectable impact on intertidal benthic communities. Overall, the recorded intertidal benthic communities since power station operations began are typical of those expected within Milford Haven with any possible influence restricted to a localised area of the shore just to the west of the outfall. Any observed annual changes are likely due to natural drivers influencing community structure.

Monitoring	Conclusion
Subtidal benthic ecology	There is no evidence that power station operation has influenced the physico-chemical characteristics of the sediments either within Pennar Gut or in the main body of Milford Haven. Similarly, there is no evidence that power station operation has affected the benthic infauna at any of the survey sites within Pennar Gut and Milford Haven. Instead, it is considered that any biological effects associated with sediment quality are minor, chronic (rather than acute) and likely to be associated with long-term human related activities throughout the waterway.
Subtidal epifauna	There is no evidence that power station operation is having any impact on subtidal epifauna inhabiting hard substrates. No discernible temporal or spatial trend has been identified. Any minor differences observed between years are not considered to be influenced by temperature or residual oxidant changes resulting from power station operation. Instead, it is considered to be due to natural changes in the existing communities..
Entrapment	There are some differences in the abundance and biomass of fish entrapped annually at the power station, generally reflecting the patterns observed within the Haven. However, catches represent a very small ecological footprint when considered in relation to other pressures such as natural predation by seabirds, otters and seals as well as mortality from commercial fishing. The results of the environmental monitoring programme carried out in the wider Haven demonstrate that ongoing entrapment pressure is neither having a detectable nor significant ecological effect on fish at the species or community level.

3. Map of the Site Locations of Pembroke Power Station Marine Environmental Monitoring



Appendix A. Environmental monitoring summaries

A.1 Bathymetry

A.1.1 Reasons for monitoring

The original survey program (EA/EPR/DP3333TA/PO4a) included a series of bathymetric surveys of the intake and outfall area that covered the period before and after the intake and outfall channels were dredged. The PO4a program included 12 months of monitoring during the initial operation of the power plant,

It was noted that "apart from monitoring sedimentation in the dredged channels and hence providing a basis for predicting the need for maintenance dredging of the intake approach channel, these surveys will provide a record of any changes in the bathymetry of the part of Pwllcrochan Flats in the vicinity of the outfall channel, from whatever cause these might arise."

Figure A-1. View of Pembroke Power Station intake and surrounding bathymetry.

Bathymetric surveys have continued outside of the agreed (P04a) program to inform operational decisions around the need for dredging.

A.1.2 Methods

The surveys used standard sonar depth sounding techniques, The data was processed and analysed by the survey company to provide bathymetry maps as well as to calculate rates of change.

A.1.3 Observations

The last bathymetry survey report[1] notes that the seabed levels for the outfall area had been reasonably stable. Over the wider monitoring area of the Pwllcrochan Flats no notable sedimentation or erosion had occurred since the completion of dredging activities. Sedimentation has occurred in the intake channel at a fairly steady rate. RWE have undertaken maintenance dredges in the intake channel during 2016 and 2023.

A.1.4 Conclusion

There is no evidence that the power station is having a detrimental impact on the seabed levels around the intake and outfall areas. There have been some changes in seabed levels but these are in line with what was expected and not of ecological significance.

A.1.5 Future monitoring

Monitoring to inform operational decisions about dredging the intake channel will continue.

[1] Anthony Bates Review of December 2020 Monitoring Survey

A.2 Marine water quality

Water quality was monitored in Milford Haven across several locations and for various parameters.

Figure A-2. Survey vessel for water quality assessment.

A.2.1 Reasons for Monitoring

CW discharged to the Haven during operation has the potential to change water chemistry. Moreover, background chemistry could interact with other influences from power station operation such as temperature.

A.2.2 Methods

Water quality monitoring has been undertaken on a seasonal basis since 2006. Since 2017, the monitoring of several physico-chemical parameters, including nutrients, has been carried out on a monthly basis. A total of 10 sites was surveyed, covering an area of approximately 2.5 km^2 both upstream and downstream of the power station outfall. Physico-chemical (e.g., salinity, temperature, dissolved oxygen) and chemical parameters (e.g. nutrients, metals, total petroleum hydrocarbons) have been monitored in agreement with NRW; sampling followed the guidelines and best practice techniques of Water Framework Directive (WFD). The suite of determinands monitored has been modified over the years, in agreement with NRW, to increase the understanding of the chemical water conditions in Milford Haven.

A.2.3 Observations

With the agreement of NRW, in 2015 the monitoring of determinands such as anions/cations, metals and organic compounds was ceased. With a few exceptions of elevated water temperatures localised at the CW outfall, the majority of other monitored chemical and physico-chemical parameters were within the range of the previously collected, pre-operational baseline data, and were within the range expected in an estuarine environment.. Temperature is discussed in more detail in a separate section. Chlorination by-products (CBPs) are a standalone part of the programme and are also discussed separately[2].

A.2.4 Conclusion

There is no evidence that power station activity has had any ecologically significant effect in the overall water quality in Milford Haven, and therefore the integrity of the SAC has not been affected from a water quality perspective. There are no significant differences in physico-chemical parameters between years, and seasonal and inter-annual variations are considered related to natural processes rather than a direct effect from the power station.

A.2.5 Future monitoring

A reduced monitoring programme was agreed with NRW, which will continue to provide ongoing post-operational water quality information.

[2] The potential for ecological effects due to exceedance of the TRO Environmental Quality Standard (EQS) would be expected to be confined to the vicinity of the zone affected by the short-term cooling water plume.

A.3 Milford Haven water temperature

Water temperature has been monitored since 2011 at fixed locations in the Haven, extending from near the mouth of the waterway to upstream of the Cleddau toll bridge. The monitoring points and their location in relation to the power station are shown in Figure A-3. It has been agreed with NRW to reduce the number of moorings within the Haven from 2023 onwards.

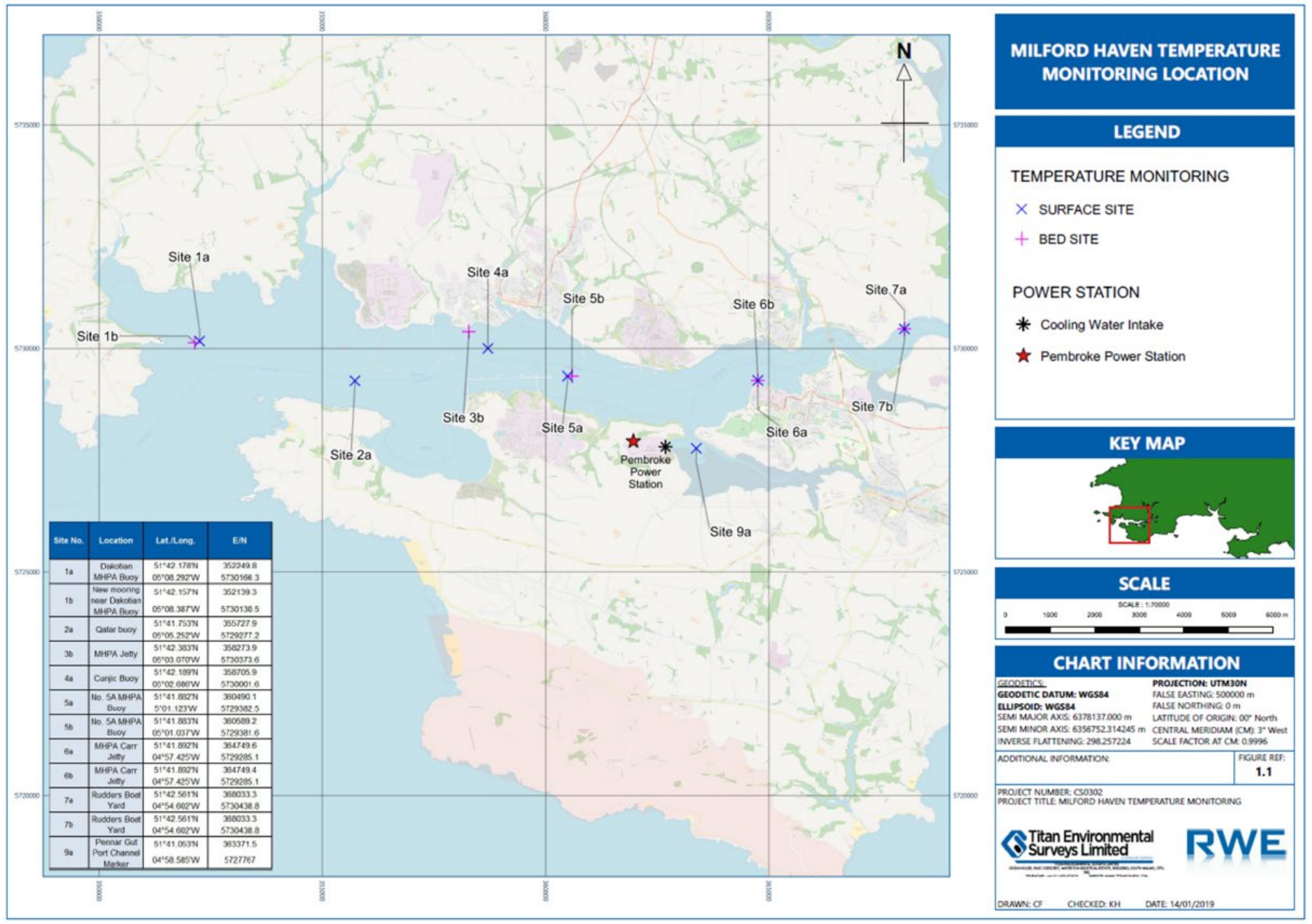


Figure A-3. Location of the mooring sites (2011 to 2022 inclusive).

A.3.1 Reasons for monitoring

The monitoring has been undertaken to understand the factors that influence the variation of water temperature within Milford Haven and to identify the influence of the CW discharge,

A.3.2 Methods

The reporting of the temperature data has evolved over the years to involve a frequency analysis. Essentially, the data are processed to extract the different timescales over which the water temperature varies. These timescales include the seasonal, the spring-neap tidal cycle, and daily down to hourly scales. The analysis has been developed and used to identify the short term influence from the power station cooling water discharge as it passes over some of the mooring locations.

In addition to the analysis of the observed temperature data RWE undertake a modelling study to reproduce the observed water temperature. This study includes the influence of the variation of seawater, meteorology, river flows, temperatures, and the power station CW system operation.

A.3.3 Observations

Natural processes, including the seasonally changing balance of net radiation and interaction with the atmosphere, tidal forcing, meteorology, and fluvial flow are the dominant factors influencing the observed temperature changes on all timescales. At the temperature monitoring network locations the power station operation is generally a modest perturbation on the natural temperature variation. At some of the sites (4a, 5a, 5b and 9a see Figure 3-1) the analysis found short term spikes of duration of some 10s of minutes superimposed on the underlying variation on some tides. There was a clear correlation between the power station heat flux and the magnitude of the spikes. The temperature modelling work feeds directly into the ecological monitoring reporting where its potential significance for any ecological change observed is considered. Temperature spikes of the above magnitude and duration at inner estuary locations are unlikely to be of ecological significance.

A.3.4 Conclusion

Meteorology is a key driver of the seasonal variation in measured water temperature and the spring-neap tidal cycle is a driver of the medium term variation in measured water temperature. The analysis also demonstrates that although meteorology is likely to be an influence on the medium term variation in water temperature, the influence of meteorology on medium term variation in water temperature will be much weaker than on seasonal variation[3]. The model was found to reproduce many of the principal features of the complex temperature record at all sites allowing informed inference of the relative contributions of short-term and long-term power station temperature fields, natural and potentially other influences.

A.3.5 Future monitoring

As noted previously it has been agreed with NRW that the number of monitoring location will be reduced to a single site from 2023 onwards. Future reporting will reflect the reduced scale of the temperature monitoring.

A.3.6 Climate change simulations

The operational permit[4] requires RWE to undertake additional hydrodynamic modelling every six years that includes the latest climate change predictions. The results of the latest study[5], undertaken in 2023, show limited change in the size of temperature mixing zones and hence no requirement to change the manner in which the permitted activities are carried out.

3 Analysis of the 2022 Milford Haven Temperature Monitoring Data ENV/734/2024

4 Section 2.3.6 of EPR/DP3333TA

5 Modelling the influence of Climate Change at Pembroke Power Station ENV/720/2023

A.4 Chlorination By-Products (CBPs) – water and biota

CBPs were monitored at various locations in Milford Haven, assessing concentrations in the water and in the tissues of marine animals. Changes in the physiological condition of these animals were also assessed. CBPs monitoring has been undertaken since 2012.

Figure A-4. Collection of biota samples for CBP tissue analysis.

A.4.1 Reasons for monitoring

Oxidant dosing of the CW is undertaken to prevent biofouling, resulting in the formation of CBPs which are then released into Milford Haven through the returned CW. CBPs at high concentrations can be toxic to marine organisms and can accumulate in the tissues of some animals through ingestion (bioaccumulation). Discharge concentrations associated with the Pembroke power station CW system operation are below the threshold for harm to aquatic organisms.

A.4.2 Methods

Water samples were collected from the power station and at various locations in Milford Haven. The samples were analysed for concentrations of CBPs; all methodologies followed best practice techniques. The bioaccumulation assessment required the collection of animals that feed by filtering water (mussels) or grazing on algae (periwinkles) at increasing distance from the CW outfall. Their tissues were analysed for CBP concentrations and a variety of biometric parameters (e.g., ratio of shell weight to shell length or height) were measured to assess their condition. All methodologies followed best practice techniques.

A.4.3 Observations

CBP concentrations from water samples collected on the power station and within Milford Haven have remained considerably low when compared with levels reported around other once-through cooled (OTC) coastal and estuarine power stations. Concentrations reported in 2022 within the area around the outfall and the outfall itself were considered very low even when compared with all other years. Initial monitoring in 2012 and 2013, prior to and after the initial use of oxidant, showed some post-dosing changes in the size and weight ratios of blue mussels. However, these changes did not correlate with proximity of the sites to the CW outfall, and tissue analysis showed minimal or no uptake of CBPs by mussels both pre- and post-dosing. Monitoring of periwinkles pre- and post-dosing between 2014 and 2022 did not show any important changes in their physiological condition. CBP concentrations in periwinkle tissues to date have always been below detection limits.

A.4.4 Observations

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A.4.5 Conclusion

There is no evidence of detrimental impacts of CBPs on marine communities within Milford Haven. The observed CBP concentrations in both the Milford Haven watercourse and the tissue of potentially vulnerable organisms were very low. It is considered that any observed variability in the condition of the organisms monitored is related to the variability in other environmental factors with no evidence of any influence from the power station operation.

A.4.6 Future monitoring

CBP monitoring of both water and biota will continue as part of the power station marine environmental monitoring programme.

A.5 Phytoplankton

Phytoplankton abundance and species composition was monitored at various locations in Milford Haven.

A.5.1 Reasons for monitoring

Phytoplankton are microscopic algae living in the water column and forming the base of the marine food web. Their growth is influenced by several factors, both natural and due to human activity, including water temperature, daylight, nutrient availability, etc. The use of oxidant within the CW system could also influence phytoplankton growth.

A.5.2 Methods

Between 2007 and 2013, samples were collected from the Haven twice a year, in April and October. High-resolution monitoring of phytoplankton species composition and abundance began in 2013, with samples collected monthly between March and October.

Samples were collected following WFD methodology; three sites were sampled until 2009, 10 sites in 2011 – 2012 and five sites since 2013 in favour of more frequent monitoring. All changes to the monitoring programme were agreed with NRW.

A.5.3 Observations

Overall, phytoplankton communities within Milford Haven have consistently shown high variability throughout the monitoring period (2013 to 2022) with changes in the timing of peak abundances and dominant species observed in line with those observed in other estuarine environments and the adjacent Celtic and Irish Seas. The main controlling factors of phytoplankton development within the estuary were residence times, light and nutrient availability, in addition to a naturally patchy distribution throughout the Haven.

A.5.4 Conclusion

There is no evidence that power station operation is having a discernible impact on phytoplankton populations. Based on both the phytoplankton community data examined and published literature reviewed, it can be concluded that effects on phytoplankton from thermal, chemical and mechanical stress resulting from power station operation is negligible. The observed year-to-year variability in the magnitude and timing of peak abundance is largely a result of natural variability in riverine discharge and turbidity levels, which affect both plankton residence times and light availability within the estuary.

A.5.5 Future monitoring

Monitoring is continuing at a monthly frequency in order to obtain more high-resolution data to better understand phytoplankton changes within Milford Haven.

A.6 Zooplankton

Zooplankton abundance and species composition were monitored at various locations in Milford Haven.

A.6.1 Reasons for monitoring

Zooplankton are microscopic animals living in the water column. Zooplankton communities are closely related to those of phytoplankton and form an important part of the wider marine food web. The use of oxidant within the CW system may influence zooplankton.

Figure A-5. Processing samples in the laboratory.

A.6.2 Methods

Zooplankton species composition and abundance in Milford Haven were monitored seasonally (spring, summer, autumn and winter) during 2006, 2007 and 2009, then on a bi-annual (spring and autumn) basis since 2011. Three sites were sampled in 2007 and 2009; this has increased to 10 sites since 2011, in agreement with NRW. Sample collection and analysis followed best practice techniques.

A.6.3 Observations

Milford Haven supports a wide range of zooplankton like those reported in other estuaries. Zooplankton species composition has remained relatively stable since 2009, although the numbers of each species present at any time have been highly variable through the years, especially among spring populations. This sort of variability is typical of zooplankton in estuaries. Several non-native species are present in the zooplankton examined, possibly as a result of ballast water discharges from international shipping. Their arrival in Milford Haven is not related to the power station operation.

A.6.4 Conclusion

There is no evidence that the power station operation is having a detectable impact on zooplankton populations. Community dynamics and fluctuations in abundance remain consistent with those expected, based on natural seasonal variations in temperature and salinity within an estuarine environment.

A.6.5 Future monitoring

Monitoring will continue at the current level to better understand zooplankton community dynamics in Milford Haven and determine the ability of non-native species of zooplankton to become established in these waters.

A.7 Ichthyoplankton

Ichthyoplankton abundance and species composition was monitored at various sites in Milford Haven.

Figure A-6. Gulf sampler for ichthyoplankton tows.

A.7.1 Reasons for monitoring

Many of the fish species present in Milford Haven spawn within the estuary, while larvae of other species use the estuary as nursery grounds. Ichthyoplankton could be affected by the increased temperature and oxidant present in the CW plume. Entrainment of larvae in the CW system could also affect fish populations.

A.7.2 Methods

The abundance and species composition of fish eggs and larvae were surveyed during the peak abundance period (May – July) since 2007 and extended to April – August since 2015. Samples were collected at three sites on both ebb and flood tides in the vicinity of the power station following best practice techniques.

A.7.3 Observations

Ichthyoplankton species composition and peak abundance times have remained similar throughout the monitoring period. High variability in ichthyoplankton abundance was evident during both pre- and post-commissioning with differences between years a result of fluctuations in the abundance of common species. However, the overall patterns observed in any one year have remained the same. There has been an overall increase in the ichthyoplankton abundance and species diversity after a minimum recorded in 2012.

A.7.4 Conclusion

There is no evidence that power station operation is having a detectable impact on ichthyoplankton communities.

A.7.5 Future monitoring

Monitoring is continuing during the extended April – August period, to better understand community changes within Milford Haven.

A.8 Intertidal and subtidal fish

Fish abundance and species composition have been monitored in Milford Haven at various locations.

A.8.1 Reasons for monitoring

Milford Haven is an important nursery area for fish. Fish communities inhabiting the subtidal and intertidal areas of Milford Haven could be affected by the increased temperature and oxidant present in the CW returned to the Haven. Impingement of fish on the CW intake screens could also affect fish populations.

A.8.2 Methods

Intertidal and subtidal fish abundance and species composition continue to be surveyed seasonally, since 2009. Survey sites included seine net beaches (seven in total) and trawl locations in the vicinity of the power station intake and outfall as well as further upstream and downstream in Milford Haven. The subtidal fish surveys undertaken to date have been reviewed on an annual basis with changes made to sites through consultation and agreement with NRW. In 2015, a five-year monitoring programme was agreed in which seven of the original 13 sites were surveyed.

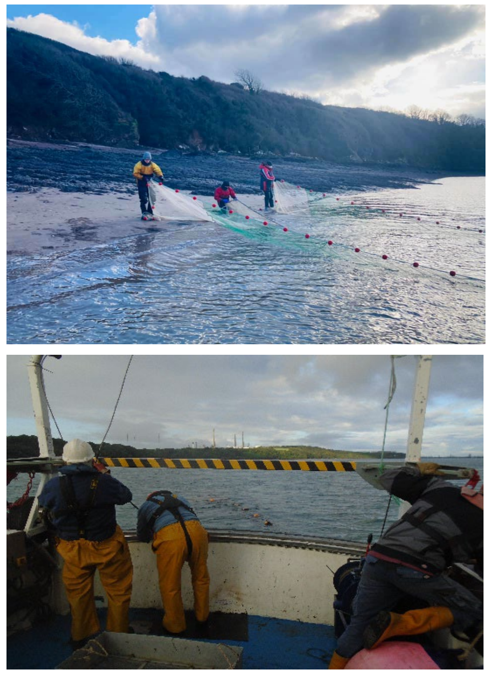

Figure A-7. Intertidal seine netting (top), subtidal trawling (bottom).

A.8.3 Observations

Overall, the seasonal fluctuations and patterns observed in the abundance and species composition of fish communities have not changed since the power station became operational. The population structure of the most common species has also remained the same since pre-commissioning. Detailed technical assessments to date have shown only small differences in the overall fish community structure within Milford Haven over the period of construction, commissioning and operation of the power station. These differences reflect the complex life histories of the most numerous species present in the study area both within and outside the Haven, rather than a shift in community structure or fish abundance. Isolated high catches of some common species have been recorded over the years; however, these species spawn outside the Haven and therefore are not solely affected by conditions within the estuary. Since 2007, a decreasing trend in annual subtidal fish catches was observed; as such it is considered that it is likely part of a longer-term trend or cyclical pattern and not associated with power station operation.

A.8.4 Conclusion

There is no evidence that power station operation is having a detectable impact on fish populations. The differences observed in fish abundance and community structure over the monitoring period, remain in line with expected natural variations and are of a magnitude and nature which is not significant from an ecological and conservational point of view. The observed variability in fish community data is the result of high mobility, seasonal behaviour and complex life histories, and would be expected to display natural variation between seasons and years.

A.8.5 Future monitoring

Fish monitoring will continue in order to ensure long term data sets are available for continual assessment of the fish community so that any effects that may potentially be linked to power station operation can be determined. Subtidal fish monitoring is continuing at the reduced number of seven sites during all seasons.

A.9 Seagrass

Seagrass beds in Pwllcrochan Flats and Pembroke River were monitored for parameters such as extent and shoot density.

A.9.1 Reasons for monitoring

Seagrass beds are an important habitat for juvenile fish and burrowing animals. They are known to be sensitive to habitat loss, smothering and sediment contamination. Dredging can result in increased sedimentation which could smother seagrass beds. Encroachment from macroalgae (i.e., advancement of nuisance green seaweed onto the seagrass beds) is also a risk in Milford Haven.

A.9.2 Methods

Seagrass beds have been monitored annually in Pennar Gut during the peak growth period since 2009 and in Pwllcrochan Flats since 2016, and bi-annually since 2019. Surveys assessed extent, density and species composition as well as sediment dwelling fauna. Sediment samples were also taken for physico-chemical analyses. The survey methodology followed WFD guidelines.

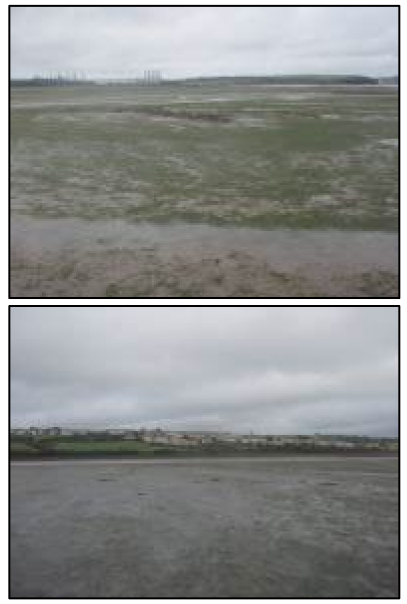

Figure A-8. Seagrass beds in Milford Haven

A.9.3 Observations

The studied seagrass beds are well established, healthy and with no signs of adverse effects, epiphytes or wasting disease. There has been significant seagrass colonisation observed in recent years on the north and south shores. The extent and density of seagrass beds Pennar Gut have shown an increasing trend, with some variations from year to year, while greater stability was observed at Pwllcrochan Flats. These variations were likely related to natural environmental factors (light availability, waves, salinity, tides, weather and climate, etc.). Following WFD protocols between 2010 and 2021, the seagrass beds in Pennar Gut were classified as being of ‘Good’ or ‘High’ ecological status. Within Pwllcrochan Flats, the seagrass bed ecological status was consistently classified as High between 2016-2021. Although nuisance macroalgae were present at the outer limits of seagrass beds, there was no evidence of encroachment on to the beds or impediment of seagrass growth.

Concentration of metals and organic compounds within the sediment varied throughout the study period, with concentrations generally within environmental guidelines and not considered to be having any effect on the seagrass health or associated fauna. This is considered to be unrelated to power station activities, likely a product of historical and current industrial activity with Milford Haven.

Sediment dwelling fauna has remained similar from year to year and was typical of the habitat surveyed.

A.9.4 Conclusion

There is no evidence that power station activities have had any measurable impact on environmental quality in relation to the seagrass beds, associated intertidal habitats and faunal communities in Pennar Gut.

A.9.5 Future monitoring

Monitoring is continuing with unchanged frequency and intensity.

A.11 Macroalgae

Macroalgal beds in Pwllcrochan Flats and Pembroke River were monitored for parameters such as extent, density and growth into the underlying sediment.

A.11.1 Reasons for monitoring

Encroachment of opportunistic/nuisance macroalgae onto seagrass beds is considered a risk in Milford Haven due to the high nutrient levels in the watercourse. Even though macroalgal growth is primarily influenced by nutrients and light availability, water temperature is also considered to play a role in promoting growth.

Figure A-9. Hover craft (top) and macroalgal beds (bottom).

A.11.2 Methods

Opportunistic/nuisance macroalgae beds in Pwllcrochan Flats and Pembroke River have been monitored annually since 2013 and bi-annually since 2019, assessing extent, density, biomass and growth into the underlying sediment. Surveys were carried out during peak growth in late summer and in the winter during the first year only. Surveys followed Environment Agency and WFD guidelines.

A.11.3 Observations

Field observations between 2013 and 2021 indicated the absence of opportunistic macroalgae from Pwllcrochan Flats during the peak growth period except in the area close to Martin's Haven in 2015. Their absence from Pwllcrochan Flats is considered to be due to the absence of sheltered conditions making this area an unsuitable habitat for opportunistic macroalgae. Opportunistic macroalgae were present within Pembroke River, however an overall decline in cover, extent and biomass have been recorded between 2013 and 2021. Following WFD protocols the ecological status for opportunistic macroalgae, calculated for Pembroke River at a local level, was 'Good' in 2013 and 2014 and 'High' between 2015 and 2021.

Although there is some variation from undisturbed conditions with regards to the total coverage of opportunistic macroalgae within Pennar Gut, macroalgae is not considered to be causing harmful effects or out-competing other species in the area, advancing onto the seagrass beds or impeding seagrass growth. These variations are likely to be due to factors such as weather and historic factors such as nutrient run-off from agriculture rather than any effect from the minor thermal input from CW returned to the Haven.

A.11.4 Conclusion

There is no evidence that the power station operation is having any impact on the macroalgae growth. Influences in promoting macroalgae growth are likely to be driven by nutrient input and by light and availability of suitable habitat, rather than an increase in the water temperature due to the CW returned to the Haven.

A.11.5 Future monitoring

Monitoring is continuing bi-annually, during the peak growth period only.

A.12 Rocky shore and low shore soft sediments

Intertidal benthic communities in Milford Haven were monitored for fauna and flora composition at various locations on the rocky shore and low shore.

A.12.1 Reasons for monitoring

Intertidal areas support diverse communities of invertebrate animals and seaweed. The CW from the power station is returned into the estuary via an outlet in a channel which transverses Pwllcrochan Flats on the southern shore of Milford Haven. Intertidal benthic habitats on this area could be affected by the warmer CW returned to the Haven and the oxidant present in the CW during dosing.

Figure A-10. Rocky shore quadrat survey.

A.12.2 Methods

Rocky shore and low, soft-sediment shore sites located on Pwllcrochan Flats were surveyed in 2006, 2008 (11 sites) and annually from 2009 to 2021 (12 sites), although no samples were taken during 2020. The species composition and abundance of fauna and flora were assessed following best practice techniques.

A.12.3 Observations

There has been little change in macroalgae at the rocky shore sites. Some temporal variations in the abundance and population structure of key macroalgal and faunal taxa were recorded, however, the general trends have been similar to other sites in Milford Haven, outside the CW influence from the power station.

Macroalgal assemblages at Pwllcrochan were described as 'High' ecological quality value for most years and 'Good' for 2013 and 2014. Infauna Quality Index scores for low shore communities were consistently described as 'High' ecological quality. Among the mid-shore, Gastropods (sea slugs & snails) and barnacles were common. In contrast an ecologically significant decline in mussels has occurred since 2010, a trend that aligns with observations made elsewhere within the Haven. The invasive slipper limpet (*Crepidula fornicata*) has shown a greater distribution along the western shore over time, while oyster numbers have remained low across Pwllcrochan Flats. Abundance of one species (*Phorcus lineatus*) has shown an increasing trend over time, likely reflecting regional scale climate change. Low shore macrofaunal communities remain representative of their naturally variable habitats with only temporary changes observed and considered to be related to natural variability in abiotic and biotic drivers.

A.12.4 Conclusion

There is no evidence that power station operation is having a detectable impact on intertidal benthic communities. Overall, the intertidal benthic communities recorded since the power station became operational are typical of those expected within Milford Haven. Any year-on-year community changes observed are likely due to natural drivers and have not compromised the integrity of qualifying features of the Pembrokeshire Marine SAC.

A.12.5 Future monitoring

Starting in 2021, monitoring will continue every three years (next survey to be undertaken in 2024) as agreed with NRW.

A.13 Subtidal sediment quality and benthic ecology

Subtidal sediments were monitored for various physico-chemical parameters and benthic fauna composition at various locations.

A.13.1 Reasons for monitoring

Seabed sediments act as the ultimate sink for contaminants in marine and estuarine environments and therefore sediments and the animals living within are a useful indicator of impacts associated with human related influences. Furthermore, the distribution and abundance of these animals could be affected by the warmer CW returned to the Haven and the oxidant present in the CW at certain times of the year.

A.13.2 Methods

Species composition, abundance and biomass of sediment dwelling animals has been monitored annually since 2010 at several sites in the vicinity of the CW outfall at Pwllcrochan Flats, within Pennar Gut and also at a number of sites further afield. Sediment samples for physico-chemical analyses were also collected. Surveys and sample analyses followed best practice techniques.

A.13.3 Observations

Some variation in subtidal benthic community features was reported during the monitoring period, where until 2018 communities were of 'High' ecological quality with no indication of disturbance or stress associated with the power station. Observed spatial patterns were primarily related to physical habitat characteristics (e.g., sediment particle size) as well as depth. Modelled bed temperatures were indicated to have a negligible effect on the distribution of the benthic communities. Although, within Pennar Gut there does appear to be some influence from total PAH (polyaromatic hydrocarbons) and heavy metal concentrations of mercury and cadmium.

Concentrations of some metals in the sediments were elevated above background levels throughout much of the study area, however concentrations were similar pre- and post-commissioning of the power station and were below the Probable Effect Level (PEL). Sediment-bound Polycyclic Aromatic Hydrocarbons (PAHs) concentrations post-operation were similar to those previously reported from the survey area and to levels observed in sediments from other UK locations. Although at site 15 (closest to Pembroke Dock) several PAH concentrations exceeded PELs between 2014 and 2021.

A.13.4 Conclusion

There is no evidence that construction and operation of the power station has influenced benthic fauna and physico-chemical characteristics of sediments within Milford Haven with no observed impact upon the integrity of the Pembrokeshire Marine SAC. Considering the sediment quality guidelines for the protection of aquatic life (CCME, 2001), the levels of metals, PAHs and other organic pollutants recorded are not considered to represent any significant risks to the benthic communities, supported by the continued abundance of sensitive organisms such as the amphipod, *Ampelisca* spp. The considerable amounts of sediment-bound hydrocarbons in Milford Haven are likely due to the chronic inputs from industrial scale petrochemical discharges and associated dredging activities, which are unlikely to increase due to the comparatively modest power station operations.

A.13.5 Future monitoring

Since 2021, monitoring will continue every three years (next survey to be undertaken in 2024) as agreed with NRW.

A.14 Subtidal epifauna

Hard substrates (reefs) were monitored for faunal species composition and assessment of the habitats present at various locations.

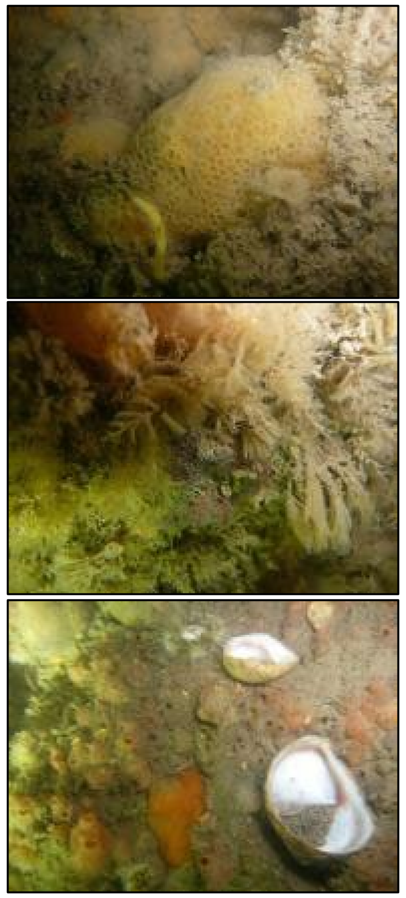

Figure A-11. Subtidal habitats encountered during monitoring in Milford Haven.

A.14.1 Reasons for monitoring

The Pembrokeshire SAC, which includes Milford Haven, is considered one of the best areas in the UK for reef habitats; reefs are a Habitats Directive Annex I habitat type. Several reef habitats are located near to the end of the power station outfall channel. The reef communities, including fauna inhabiting the reefs (epifauna), could be affected by the warmer CW returned to the Haven and the oxidant present in the CW at certain times of the year.

A.14.2 Methods

Four sites have been monitored since 2011; three sites are situated at increasing distances downstream from the end of the CW outfall channel (on the south side of the Haven) that runs across Pwllcrochan Flats. The fourth site is a reference site located 5 km upstream of the outfall. The reef fauna and habitats were assessed following best practice techniques. Temperature was also recorded at each site using data loggers.

Given the lack of ecologically significant changes recorded at any of the sites between 2012 and 2019, it was agreed with NRW that monitoring should be scaled down to a reduced intensity from 2020 onward. Therefore, in 2020 and 2021 a programme of site maintenance (checking/replacing site marker pins), temperature logger replacement and Marine Nature Conservation Review (MNCR) Phase II survey was instigated. In 2022, a fully quantitative survey was undertaken.

A.14.3 Observations

The biotope for all sites remained unchanged, dominated by cushion sponges, hydroids and ascidians on turbid tide-swept sheltered circalittoral rock.

At the reference site beneath the Cleddau Bridge, the increased colonisation of the serpulid tube worms *Salmacina/Filograna* sp. (which were recorded as 'abundant' on the SACFOR scale in 2020) was in decline, with the site community returning to a more 'usual' composition observed throughout the preceding years. The decline is considered highly unlikely to be related to power station operations given the lack of similar recruitment to the other down-stream sites. Water temperature across all sites remained within the range recorded since 2011 and therefore there is no reason to believe the colonisation at the reference site was temperature related.

A.14.4 Conclusion

There is no evidence that power station operations are having any impact on subtidal epifauna inhabiting hard substrates. Any differences observed between years are not considered to be influenced by temperature or residual oxidant changes resulting from power station operation, instead are believed to be due to natural changes in the existing communities.

A.14.5 Future monitoring

Maintenance dive surveys will be completed in 2023 and 2024 with a fully quantitative quadrat survey scheduled for summer 2025.

A.15 Entrapment

Abstraction of CW unavoidably leads to the entry, or entrapment, of organisms into the CW system. During entrapment organisms that are too large to go through the CW intake screens mesh (e.g., juvenile and adult fish, invertebrates and seaweed) are retained or impinged on the screens. The organisms that are smaller and can penetrate the CW screens (e.g., fish larvae/ichthyoplankton, phytoplankton and zooplankton) enter the CW system and are returned to the estuary via the CW circuit; this process is called entrainment.

A.15.1 Reasons for monitoring

The impact of CW abstraction is minimised through the state-of-the-art CW system detailed in section 1.2, including measures aimed at deterring and/or preventing fish from entering the CW intake. Some fish still enter the system and could be lost from the ecosystem as viable individuals either through mortality on the CW screens (juvenile and adult fish) or mortality during transit through the CW system (fish larvae, plankton). The purpose of entrapment monitoring is to quantify the residual effects of intake operation, i.e., the quantity, biomass (weight) and species of fish that enter the CW system either through impingement or entrainment.

A.15.2 Methods

Entrapment has been assessed since 2012 through impingement surveys (up to 40 per year) and several entrainment surveys (the frequency of which have changed through the programme with at present 9 surveys completed). The number, biomass, length and species of the fish impinged were assessed and the number and species of invertebrate animals recorded; the volume and species composition of seaweed and seagrass were also recorded. The abundance and species of the fish larvae entrained were also assessed.

A.15.3 Observations

Overall, the long-term annual entrapment pressure from the station has declined.

The numbers of fish impinged has shown a declining trend since 2012, where species with the highest abundances represented the same dominant species recorded from the Haven reflecting greater fish abundances within the Haven. Entrainment of fish larvae generally followed the observed patterns in fish impingement, with greater stability and no evidence of preferential entrainment of specific species, for most cases.

The annual entrapment pressure from power station operation between 2012 and 2022 was minimal when compared to other pressures, both ecological (e.g., predation by seabirds, otters or seals) and anthropogenic (e.g., commercial fishing). There is no evidence to demonstrate that entrainment at Pembroke Power Station is applying a detectable or ecologically significant pressure on wider fish populations.

A.15.4 Conclusion

There are some differences in the abundance and biomass of fish entrapped annually at Pembroke. However, when interpreted in an ecologically meaningful way, these catches represent a very small ecological footprint when considered in relation to other pressures such as natural predation by seabirds, otters and seals as well as fishing mortality. The results of the environmental monitoring programme carried out in the wider Haven demonstrate that ongoing entrapment pressure is not having a detectable or significant ecological effect on fish at the species or community level.

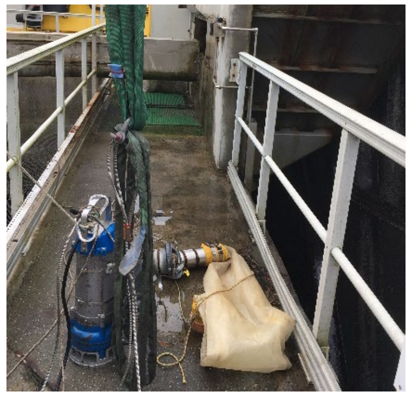

Figure A-12. Entrainment pump and net ready to be deployed.

A.15.5 Future monitoring

Monitoring is continuing with additional entrainment surveys either side of the peak abundance period (i.e., in April and August) to coincide with the expansion of the ichthyoplankton monitoring within the estuary.