RWE

Summary of Supporting Information for the Renewal of Pembroke Power Station Abstraction License

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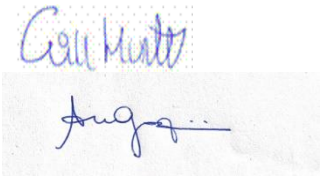	
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Summary

This report has been produced to support an application by RWE Generation UK plc (RWE) to renew on a like for like basis the water abstraction license number 22/61/6/0156 granted to Pembroke Power Station on 03/02/2009 (the Abstraction Licence Renewal). The Power Station is owned and operated by RWE in accordance with the conditions set in its abstraction licence, Environmental Permit and Section 36 Consent. Commercial operation of the Station commenced in September 2012.

The cooling water system at Pembroke Power Station was designed in line with Best Practice. It incorporates an intake designed to limit the velocity of the induced flow. The station is fitted with an acoustic fish deterrent system and strobes; these behavioural deterrents and the low intake velocity help to limit the number of fish drawn into the station. The main screens are fitted with a fish recovery and return system which directs fish caught on the screens to a holding tank before they are released at a suitable tidal state to avoid recirculation.

This report provides information to demonstrate that the proposed Abstraction Licence Renewal meets NRW's three tests of continued environmental sustainability, continued justification of need for the water abstraction and that the water is used efficiently.

The environmental sustainability test has been demonstrated by three assessments. These are: a Marine Conservation Zone Assessment, a Water Framework Directive

Assessment and a Report to Inform an Appropriate Assessment (RIAA). These three reports themselves draw on the extensive environmental monitoring program agreed with NRW as a requirement of the station's operational permit (Pembroke Environmental Monitoring Program). A Non-Technical Summary of the monitoring program to date has also been provided. The monitoring program and reporting has evolved over the life of the station to reflect NRW's requirements. Overall, the assessments undertaken to support the renewal application concluded that the continuing abstraction will meet the three required tests. In particular, the RIAA concluded that "*Pembroke (alone or in combination with other plans or projects) will not have an adverse effect on the integrity of any European designated sites in view of that sites conservation objectives.*"

Pembroke Power Station continues to need access to water for cooling purposes. Use of the water for cooling helps to ensure Pembroke has a very high thermal efficiency, thereby reducing greenhouse gas emissions per unit of electricity generation. The firm, flexible generation provided by Pembroke Power Station has a key role in ensuring the security of supply of the UK electricity system and in supporting Wales and the UK's decarbonisation plans. RWE continue to invest in system maintenance and improvements to ensure that efficient operation of the abstraction continues.

This report also provides answers to the Additional Information requested by NRW (see Appendix A) to inform the Abstraction Licence Renewal application, by both signposting to other reports and directly answering some questions.

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1. Introduction

Pembroke Power Station is a Combined Cycle Gas Turbine (CCGT) power plant which operates under the Environmental Permit EPR/DP3333TA. The station abstracts water from Pennar Gut in accordance with the abstraction license numbered 22/61/6/0156 granted by Natural Resources Wales (NRW) on 3rd March 2009, which expires on the 31st March 2025.

RWE is applying to renew Pembroke's abstraction license to allow the station to continue to operate. This is a like for like renewal with no proposed changes to the volume or rate of abstraction, its use, purpose or point of discharge. The renewal is captured by section 46A of Water Resources Act 1991.

This report has been written to provide information in support of this application for renewal of Pembroke Power Station's water abstraction license 22/61/6/0156 (the Abstraction Renewal). The report has been structured to provide the information required by statute and published guidance as well as the information identified by NRW (NRW 2023b) in a letter dated 23rd November 2023 (the Additional Information) in order to facilitate the renewal process and validate the application.

In addition to this report, the following documents are submitted in support of the Abstraction Renewal Application:

- Application Form,
- Marine Conservation Zone Assessment,
- Water Framework Directive Assessment,
- Report to Inform an Appropriate Assessment (RIAA),
- Non-technical summary of the ongoing Pembroke Environmental Monitoring Program.
- Pembroke Abstraction Supporting Information,
- SSSI Assessment,
- Pembroke Abstraction Supporting Information,
- Raw Entrapment Data.xlsx.

1.1. The Applicant

The RWE Group is a leading energy company holding a diverse portfolio of offshore wind, hydro, onshore wind, solar, nuclear, biomass and gas, with four main operating companies in the UK, including RWE Generation UK plc (RWE). RWE provides firm, flexible thermal gas-fired generation with around 7GW of modern and efficient operational capacity in the UK. RWE Generation UK plc (RWE) is the owner and operator of the Pembroke Power Station and as such is the applicant for the proposed Abstraction Licence Renewal.

The RWE Group is Wales' largest power producer, and the country's number one renewable energy generator. The RWE Group has a target to be climate neutral by 2040, and also plays a critical role in driving Wales' decarbonisation, working with Welsh Government and wider partner organisations. Through our past and future investments, the RWE operating companies in the UK are helping to create a clean, affordable and

secure power system, which can act as the springboard to the decarbonisation of wider economic sectors across Wales, such as industry and transport.

The RWE Group is currently involved in over 3 gigawatts (GW) of power generation in Wales across 12 sites, of which around 1GW is renewable. Our existing renewable energy portfolio already generates one third of Wales' renewable energy production – enough to power 550,000 homes - whilst our Pembroke power station, which has ongoing plans for decarbonisation as part of the Pembroke Net Zero Centre, powers an additional 3.5 million homes. The Pembroke Net Zero Centre will include technologies such as batteries, green hydrogen, carbon capture and synchronous condensers.

Over the last decade, the RWE group and partners have invested over £3 billion to deliver energy projects in Wales, including Pembroke Power Station, the Gwynt y Môr Offshore Wind Farm, and around £250m building onshore wind projects at Brechfa Forest West, Clocaenog Forest and Mynydd y Gwair. We also have an ambitious development pipeline, including 7 onshore and 1 offshore wind projects.

2. Basis for the Abstraction License Renewal

The relevant published guidance from NRW, "Apply for a water abstraction or impoundment licence'[1] contains the following policy:

> *"Any abstraction licence issued will be time limited. If your abstraction licence has an expiry date in accordance with the relevant Catchment Abstraction Management Strategy it will have a presumption of renewal where the following tests are met:*
>
> - *continued environmental sustainability*
> - *continued justification of need for the water*
> - *water is used efficiently*
>
> *We must receive the application to renew your licence or time-limited condition in your licence at least 3 months before your licence is due to expire."*

Therefore, it is envisaged that abstraction licences whose expiry date accords with the relevant Catchment Abstraction Management Strategy (CAMS) will have a presumption of renewal where the above tests are met. Such tests have been, to date, confirmed to be met by the continued permitted day to day operation of Pembroke Power Station. RWE is applying to renew its abstraction in identical terms to the existing license.

Furthermore, the Water Resources Act 1991 provides for business continuity by specifying that an existing licence will stay in force provided a valid application is made before three months from its expiry.

> ***"46A Limited extension of abstraction licence validity***
>
> *(1) If the condition in subsection (2) below is met, a full licence or a transfer licence whose term exceeded twelve months but whose expiry date ("the expiry date") has*

[1] *https://naturalresources.wales/permits-and-permissions/water-abstraction-and-impoundment/apply-for-a-water-abstraction-or-impoundment-licence/?lang=en*

passed shall be treated for all the purposes of this Act as not expiring until the date mentioned in subsection (4) below.
(2) The condition is that the [appropriate agency] receives, not later than the beginning of the period of three months ending on the expiry date (or such later date before the expiry date as the [appropriate agency] agrees), a valid application for a new licence...
.....
(3) For the purposes of subsection (2) above, a "valid" application is one which complies with all the requirements of this Act in relation to the making of applications for licences of the type in question.
(4) The date referred to in subsection (1) above is whichever is the later of–
(a) if a new licence is granted (whether or not on the terms applied for), the date on which it takes effect;
(b) otherwise–
(i) except where the Secretary of State calls in an application under section 41above, the expiry of the period for appealing under section 43above, or if an appeal is brought, the date of its withdrawal; or
(ii) where the Secretary of State decides (undersection 42 or 44 above) that no licence is to be granted, the date on which that decision is notified to the applicant."

It is therefore clear that the timing of renewal is of essence for the purposes of business continuity. This is particularly important for Pembroke Power Station given its role in ensuring security of electricity supply. Therefore, RWE has taken all reasonable steps in order to provide an early application in May 2024. Prior to this, RWE sought engagement with NRW on the license renewal in August 2022. This led to an advice letter being issued by NRW on 23rd November 2023 which gave more detail on the information (the Additional Information) that NRW considered necessary to support the Abstraction Licence Renewal application. For completeness NRW's letter is reproduced at Appendix A; it suggested six key issues to be looked at and identified the need to consider impacts on SSSI. Appendix A also contains the text of a subsequent email from NRW that restates the original six key issues and adds a seventh requiring assessment of the impact of continued abstraction in combination with the temperature rise resulting from the operation of the Power Station discharge.

Details of how the three renewal tests continue to be met and of the Additional Information provided is outlined in the following sections.

3. Environmental Acceptability of the Abstraction

The first of the three tests for renewal of an abstraction license is a need to demonstrate that the abstraction is not causing unacceptable damage to the environment.

Pembroke Power Station operates under an environmental permit numbered EPR/DP333TA which requires the station to undertake comprehensive ongoing monitoring of all of its operational environmental impacts (the Pembroke Environmental Monitoring Program). The scope of the program, surveys and reporting cycle has been agreed fully with NRW, in discharge of its duties as regulator under the Environmental Permitting Regulations 2016, including the protection of designated sites in accordance with Article 6(2) of the Habitats Directive and the protection of the environment as a whole.

This report signposts to a number of dedicated assessments that have been produced to further demonstrate the continued environmental acceptability of the existing and renewed abstraction, as already established by the Pembroke Environmental Monitoring Program. These are:

- Marine Conservation Zone Assessment,
- Water Framework Directive Assessment,
- Report to Inform an Appropriate Assessment (RIAA) and
- Non-Technical Summary of the ongoing Pembroke Environmental Monitoring Program.

A summary of the conclusions of each of these reports is outlined in the sections below.

The additional information, originally raised by NRW with regard to Pembroke Power Station's 2021 monitoring reporting and subsequently issued as Additional Information necessary to support the Abstraction Licence Renewal application, has also been provided and can be found in Appendix B.

3.1. Marine Conservation Zone Assessment Screening

A Marine Conservation Zone (MCZ) screening assessment has been undertaken. The assessment (Jacobs 2024a) "*serves to identify whether abstraction of water from Pennar Gut for use as cooling water by Pembroke power station has the potential (alone or in-combination) to cause effects on a MCZ site feature. If the potential for effects is identified, a Stage 1 assessment will further consider the extent of the potential impact of the proposed Project on the MCZ.* "

The Skomer MCZ is the closest MCZ to the site. It lies outside of Milford Haven and is 17km from the Pembroke Power Station site. The Skomer MCZ supports a number of species of national and international importance including grey seal, pink seafan, sponge communities, eelgrass and algal communities.

The MCZ screening assessment has considered all possible pathways ("*removal of non-target species, above water noise & habitat structure changes*") to impacts on the features of the Skomer MCZ. The findings of the assessment are that, given the distance of the Skomer MCZ from Pembroke Power Station and, in particular, from the zone of influence of its abstraction activities, the continued operation of its water intake via the Abstraction Licence Renewal will not significantly impact:

1. Any features of the Skomer MCZ; nor
2. the geomorphological processes on which the conservation of the features of the Skomer MCZ are dependent.

The maximum zone of influence for the cooling water abstraction was taken as the tidal excursion in Milford Haven (8.2km). A search was made for other potential projects that could in-combination with the Pembroke Power Station abstraction activities impact the MCZ using the Wales Marine Planning Portal and a search distance of 8.2 km from the power station. The assessment concluded that there "*were no other marine licence applications under consultation or granted for marine works within, or capable of affecting, this area of coastline*" and that a Stage 1 MCZ assessment was not required to inform the proposed Abstraction Licence Renewal.

Full details of the assessment can be found in the Marine Conservation Zone Assessment that accompanies this report.

3.2. Water Framework Directive Assessment

Although not specifically requested by NRW, an assessment against the objectives of the Water Framework Directive (WFD) has been undertaken by independent environmental experts, Jacobs U.K. Ltd, on behalf of RWE (Jacobs 2024b), in support of the Abstraction Licence Renewal.

The purpose of the WFD assessment is to determine if a proposed project complies with the objectives of the WFD. This is determined by identifying the relevant water bodies and the quality elements that could potentially be at risk from a proposed project. Where risks are identified then an impact assessment is carried out to determine if the project is compliant with the objectives of the WFD. The WFD assessment for the purposes of the proposed Abstraction Licence Renewal made use of a range of data sets including the Pembroke Environmental Monitoring Program reports of 2012 to 2022 which data sets and reporting include the influence of the abstraction and operation of the power station cooling water discharge. The assessment process followed published guidance by the Environment Agency 'Clearing the Waters for All'[2] and CIEEMA guidance[3] for the specification of zones of influence. Full details of all three stages of the assessment are provided in Jacobs (2024b), but for convenience the conclusions are reproduced below:

"There is no evidence that indicates abstraction related losses of fish adversely affect biological status of the waterbody. The ongoing abstraction of water at Pembroke PS therefore would not cause deterioration in the status of any quality elements in the water body in which the activity takes place (Milford Haven Inner) nor would the project prevent the water body from achieving good ecological potential. The Milford Haven Inner waterbody has continued to be classified as good for fish, during the operation of the current abstraction licence.

The assessment considered the potential for the fish quality element in river water bodies to be affected by the loss of migratory species which form part of the riverine fish community. The assessment concluded that the impacts on migratory species are negligible and that there is no potential for deterioration of the fish quality element in any of the river water bodies, nor would the project jeopardise the ability of any of the river water bodies to achieve overall good ecological status or potential.

Consideration of WFD protected areas considered the risks to water-dependent SPAs, SACs, Nitrate Vulnerable Zones, Shellfish Waters and Bathing Waters. The assessment concluded that these sites are not at risk and that the project is compliant with other relevant legislation.

On this basis the project is considered to be fully compliant with the requirements of The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 (as amended)".

[2] Water Framework Directive assessment: estuarine and coastal waters - GOV.UK (www.gov.uk)

[3] ECIA-Guidelines-2018-Terrestrial-Freshwater-Coastal-and-Marine-V1.1.pdf (cieem.net)

Full details of the assessment carried out for the purposes of the Abstraction Licence Renewal can be found in the Water Framework Directive Assessment that accompanies this report.

3.3. Report to Inform an Appropriate Assessment (RIAA)

A Report to Inform an Appropriate Assessment (RIAA) has been undertaken to support the Abstraction Licence Renewal (Jacobs 2024c). The influence of Pembroke Power Station abstraction and discharge were included in the baseline of all data sets collected since operation began, in line with NRW's Additional Information request (NRW 2023b). The RIAA has included both Stage 1 (screening) and Stage 2 (Appropriate Assessment). The assessment included six European sites at Stage 1 and screened out three. The potential for a Likely Significant Effect was not screened out for three sites (Pembrokeshire Marine SAC, Cleddau Rivers and Skomer, Skokholm & the Seas off Pembrokeshire SPA) which were taken through to Stage 2 Assessment.

The conclusions of the Stage 2 assessment were that *"there is either no potential for an adverse effect on site integrity or any potential for the predicted effects to compromise their conservation objectives. This conclusion supports the conclusions of Pembroke Power Station's comprehensive environmental monitoring programme annually reported to NRW where no ecologically significant effects are found"*.

In addition, a search was carried out of public registers to obtain a list of developments with feasible spatial or temporal overlap with the Pembroke water abstraction licence renewal (i.e. reasonably foreseeable future projects). The search area included the full marine foraging range of qualifying features. A review of other plans and projects that could contribute to effects has established that no significant adverse in-combination effects on site integrity with other plans and projects will occur as a result of the Abstraction Licence Renewal. The RIAA concluded that it was *"considered that the continued abstraction at Pembroke (alone or in combination with other plans or projects) will not have an adverse effect on the integrity of any European designated sites in view of that sites conservation objectives."*

Full details of the assessment can be found in the RIAA that accompanies this report.

3.4. Summary of the findings of the ongoing Pembroke Environmental Monitoring Program

As noted above, Pembroke Power Station's environmental permit requires RWE to undertake a comprehensive program of environmental monitoring, as imposed by and regularly reported to NRW for their review and approval. (Pembroke Environmental Monitoring Program). This extensive monitoring program, which has an annual external cost of approximately £0.5 million, includes:

- Fish and Ichthyoplankton surveys via both sub tidal sampling and monitoring at the power station intake;
- Surveys of inter and subtidal biota;
- Surveys of eelgrass and macroalgae;

- Diver survey of subtidal reefs;
- Water quality sampling;
- For the first year of operation, the program also included monitoring of bed levels at the intake and outfall; this was then removed from the scope of the program by NRW;
- Monitoring of water temperature;
- A requirement every six years to update modelling of the thermal discharge with the latest climate change projections and to review the operation of the station in the light of this modelling.

In agreement with NRW the survey methodologies have evolved but began before the power station was commissioned in 2012, with some starting as early as 2006. There is typically a round of reviews of the monitoring reports undertaken by NRW and then feedback by RWE and its consultants on these regulatory comments. These rounds of review and discussion have helped to evolve both the monitoring and reporting. To further improve confidence in the survey findings, RWE have previously commissioned an independent review of the use of statistics in the reporting. Over time issues, such as the appropriate method to scale survey data, have been raised by NRW and following discussion any agreed changes to the methodology have been (and continue to be) taken forward in the following year's reporting.

The purpose of the data collected was to provide a baseline against which any significant changes could be measured, potential causes of any observed change investigated and any impacts from the commissioning and operational phases of the power station could be assessed. The monitoring data includes any influence from the power station abstraction in-combination with all other activities.

A Non-Technical Summary (NTS) (Jacobs 2024d) has been produced to summarise the findings of the different workstreams covered by the environmental monitoring program. The overall conclusions of Jacobs (2024d) are as follows:

> *"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 expectation 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 pressure on the fish community using Milford Haven Waterway. It is 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 physio-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. However, such differences are not considered to be of a scale, or range, of ecological or conservational significance."*

Much of the reporting covered by the NTS is looking at the significance of change observed in the past, for example the variation in the extend of benthic communities or the number of fish in subtidal surveys. One forward facing workstream discussed in the

NTS is concerned with predicting the influence of climate change on the water temperatures in the Haven. This study has relevance to the water Abstraction Licence Renewal because, while the influence of the temperature rise due to operation of the cooling water system is inherently part of the baseline of the Pembroke Environmental Monitoring Program, future conditions may differ from that baseline. As noted in the NTS, the latest modelling study undertaken in 2023 using UKCP18[4] forecasts found limited change in the size of the temperature mixing zones in the mid-2030s compared to a baseline of 2016. Given the limited change, it was concluded that the existing operational conditions imposed in the station's environmental permit and abstraction licence remain adequate and there is no need to change the manner in which the station is operated.

NRW (2023a) provided feedback on the reporting of the 2021 Pembroke Environmental Monitoring Program. These were sent to RWE in November 2023. Subsequently NRW wrote to RWE (NRW 2023b & Appendix A) in regard to the abstraction license renewal. That letter referred to the 2021 monitoring report feedback and stated that the points raised should be addressed within the renewal application. These points and another included in a subsequent email (see also Appendix A) are addressed in Appendix B of this report.

4. Continued Justification of Need for the Water

Pembroke Power Station provides 2.2GW of firm, flexible generation within the UK and remains one of the most efficient, high-merit Combined Cycle Gas Turbines (CCGT) in Europe. The cooling water system was designed and built to operate within the existing permitted flow and temperature rise constraints. The licensed abstraction is limited by instantaneous, hourly, daily and annual caps. The actual abstracted flow will vary with the level of generation and to a lesser degree with the tidal conditions. The tidal variations are due to the characteristics of the cooling system pumps. The cooling system pumps are operated to ensure the maximum permitted instantaneous flow is not exceeded.

For a once through cooling system such as that used at Pembroke, the abstracted flow and temperature rise for a given level of generation are linked, so that a reduction in flow would require an increased temperature rise between intake and discharge to achieve the same level of cooling. The Pembroke cooling system was designed to limit the temperature rise and to ensure that the flow velocity in the intake channel remains within Best Practice guidelines.

The cooling system contributes to the station's high thermal efficiency which in turn means less fuel usage and reduced atmospheric emissions such as CO_2 per unit generation compared to less efficient CCGTs. Current forecasts show that Pembroke Power Station will need to continue to provide firm, flexible generation well into the 2030's and as such will remain a notable part of the UK Critical National Infrastructure for security of energy supply.

As the level of renewables on the National Grid electricity system continues to increase, so too does generation intermittency and the firm, flexible generation provided by Pembroke Power Station plays an important role in ensuring security of supply on the journey to decarbonisation of the UK electricity system. RWE is also actively developing projects to decarbonise Pembroke Power Station by way of hydrogen combustion and carbon

[4] Welcome to UKCP (metoffice.gov.uk)

capture. Furthermore, as part of its Pembroke Net Zero Centre, several other key projects are centred around the main asset of Pembroke Power Station which will aid the transition of Wales and the UK to Net Zero.

The main cooling water system, Pembroke Power Station's reliable access to suitable quantities of abstracted water and the licence that affords that access are critical to maintaining Pembroke as a flexible generating site within the UK but also enables the power station to become a platform for future technology that will support Wales' national decarbonisation.

The current abstraction license defines the maximum flow rate ($40m^3s^{-1}$) and the hourly ($144,000m^3$), daily ($3,456,000m^3$) and annual ($1,200,000,000m^3$) volumes of water that may be abstracted for cooling purposes. RWE request, via the proposed Abstraction Licence Renewal, a like for like extension of the current abstraction license as these volumes of water are expected to continue to be required in the future.

5. Water is Used Efficiently

RWE's efficient use of the abstracted water is the focus of the following two sections. Efficient use has been interpreted as covering both why the water is used and how the abstraction and cooling water system is operated. The first subsection covers the key drivers that influence the cooling water use at Pembroke while the second outlines the activity undertaken to maintain and continually improve the system.

5.1. Efficient use of water in the generation process

The use of water for cooling at Pembroke contributes to the station's high thermal efficiency. The high thermal efficiency means that less fuel is required for each unit of electricity produced and, more importantly, that CO_2 and other emissions to the atmosphere are reduced.

The use of water cooling in electricity generation is recognised within the European Commission (EC) Industrial Cooling Best Available Technique Reference Documents (BREF) as promoting thermal efficiency[5]. Once through cooling, as is employed at Pembroke, offers potentially the highest efficiency benefit of all cooling options.

Pembroke's operational permit has two conditions (1.2.1 & 1.3,1) which require the station to minimise energy and water use respectively. Pembroke Power Station also operates in a competitive electricity market and therefore seeks to reduce operating costs (such as fuel usage) where possible whilst remaining consistent with its permit conditions. The cooling water system pumps represent a high electrical demand (each of the ten pumps are rated at 1.2MW) and there is therefore an economic driver to reduce this to the minimum operationally required to remove reject heat.

To ensure that the heat transfer from the steam cycle to the cooling water occurs as efficiently as possible, the station is permitted and equipped with the ability to dose biocide. The use of biocide reduces biofouling of the cooling system pipework and heat transfer surfaces. Biofouling, if not controlled, will increase pumping losses because of the

[5] Industrial Cooling Systems | Eippcb (europa.eu)

increased friction and will lower the efficiency of heat transfer in the condensers. Less efficient heat transfer will either require more flow for the same temperature rise across the condenser or give a higher discharge temperature if the flow remains the same. In addition to the biocide dosing system, the steam condensers are also fitted with a mechanical cleaning system that uses abrasive (taprogge) balls to ensure heat transfer surfaces are clean.

The Pembroke Environmental Monitoring Program has included specific surveys to measure residual biocide in the waters of Milford Haven as well as concentrations in the biota near the outfall. To date the conclusion of such monitoring is that "*there is no evidence of detrimental impacts of chlorination by products (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*" (Jacobs 2024d).

5.2. RWE's operation of the Cooling Water System

5.2.1. Maintenance overview

Given the importance of the cooling water system to the operation of Pembroke Power Station, RWE devote considerable engineering and financial resources in ensuring it continues to function as intended.

This section outlines both the general maintenance activities undertaken on the system and action to improve the separation efficiency of the fish recovery and return system.

5.2.2. Fish Deterrent System (FDS)

A combined acoustic (Acoustic Fish Deterrent or AFD) and high intensity strobe light fish deterrent system is installed on the intake of Pembroke Power Station. The patented SILAS® system (Synchronised Intense Light And Sound) was manufactured by Fish Guidance Systems Ltd (FGS) and was installed by OVIVO UK Ltd (OVIVO) during the spring of 2011.

The system was originally maintained by RWE (for the first 3 years of operation). During this time RWE reviewed the demand on internal resources necessary to inspect & clean these components. It was considered to be better use of resources to sub contract the fish deterrent system maintenance to the original equipment manufacturer (OEM). Therefore in 2016 RWE placed a Maintenance Contract with the OEM supplier as a total care package. Every 2 months the light and speaker elements are lifted, cleaned, inspected and changed out.

In addition to the maintenance contract and in order to maintain the system at the highest level of reliability, RWE invested circa £250k during 2018 / 2019, with a system upgrade provided and installed by the OEM.

5.2.3. Coarse screen system

Directly behind the FDS system are the 17 coarse bar screens that protect the drum screens from floating trash. Each screen consists of 10mm width bar at 50mm spacing.

The individual screens ports are evenly distributed over the entire width of the intake structure. The coarse bar screens are subject to a 6 monthly monitoring programme for lifting and cleaning as required based on the differential pressure across the screens.

5.2.4. Drum screen system

After passing through the coarse screen arrangement, the abstracted water flows to 4 rotating filter drum screens of 15.5m diameter by 2.5m wide.

The drum screens are in constant use while the power station abstracts water. There are daily operational checks carried out on the condition and performance of the drum screens. Cleaning and monitoring personnel are also deployed throughout the day to maintain the debris basket loads and also check the fish return system.

Initially maintenance of the drum screens consisted of regular checks on bearing and drive systems with visual assessments of the drum screen structures.

In 2019 RWE observed an increase in faults with retaining bolts and supporting brackets on the drum structures. Repairs were initially carried out on an 'ad hoc' basis. It soon became apparent the demand on resources was such that, a team of 3 additional mechanical personnel were employed to maintain and rectify any faults found with the drum screens and debris flushing system.

RWE are investing circa £4,000,000 in replacing the drum screens starting in 2023. To date one screen has been fully replaced and work has commenced on replacing the second, All drum replacements are currently planned to be completed by 2025, while maintaining our maintenance regimes on the operational drums.

5.2.5. Debris handling & Fish Recovery and Return system

Each drum screen incorporates a fish recovery and discharge facility, the fish are returned into a launder system constructed above deck level, where they are held in a large tank and then discharged to Pennar Gut over a defined tidal period. Debris are separately discharged into a launder and waste basket collection system.

In 2019 RWE invested £150,000 improving the fish and debris system to allow easier and more effective maintenance access to help maintain the desired system flows.

Supply pumps are located in the main pump chamber and supply high pressure (debris system) and low pressure (fish return) water to the drum screen system manifold. There are 4 high pressure and 4 low pressure pumps installed. As the screens rotate the low pressure sprays are used to direct fish towards the fish return system with a subsequent high pressure spray to remove debris.

Due to the environment these submersible pumps are used in, maintenance demands on this part of the system are also high and mainly consisting of lifting and cleaning of pumps and the discharge strainers. RWE contracted diving services in order to rectify issues with the guide rail support system.

The drum screens are equipped with a number of spray nozzles on a common header for both high and low pressure systems, Regular cleaning of the spray heads and header pipework is undertaken to ensure the flow rate remains as intended and that the flow is evenly distributed over the screen face.

5.2.6. Additional environmental work undertaken by Pembroke Power Station

In additional to its bespoke Pembroke Environmental Monitoring Program, RWE contributed to a collaborative Research and Development project of SEACAMS2 which was part funded under the European Regional Development Fund (ERDF) by the Welsh European Funding Office (WEFO), part of the Welsh Government, under the Convergence Programme for West Wales and the Valleys. The project developed genetic markers to help to identify herring stocks [Gwilliam et al 2022].

RWE also support the work of the Milford Haven Waterway Environmental Surveillance Group[6] which works to *"provide high quality environmental information…to contribute to the maintenance, enhancement and safeguard of the Waterway's rich and diverse marine environment."*

6. Proposed Abstraction expiry date

Based on the above sections, this report demonstrates that RWE meets the criteria for a like for like renewal of the abstraction license at Pembroke Power Station. In terms of the duration of a renewed license, the most recent Catchment Abstraction Management Strategy (CAMS) for the area within which the abstraction occurs was in 2014. At the time that the CAMS was produced, it confirmed that the *"next CED for the Cleddau & Pembrokeshire Coastal Rivers CAMS is 2025, and the subsequent one is 2037*[7]*"*.

RWE therefore suggest that the abstraction license is renewed with an expiry date of the 31st December 2037.

7. References

Gwilliam, M. P. S., Farrell, E., & Clarke, D. (2022) Pembroke Power Station Herring screening studies. Final Technical Report of the SEACAMS2 project (SC2-R&D-S34) with RWE Pembroke Power Station. Swansea University, 24 pp

Jacobs (2023a) Pembroke Environment Monitoring Fish Survey Report 2021
Document no: JUKL/B2386200/2021/R05
Revision no: 1

Jacobs (2023b) Quantification of Entrapment Pressure.
Document No: JUKL/B2386200/2021/R06

Jacobs (2024a) Pembroke Marine Conservation Zone Screening Assessment JUKL/B2386202/LIC/R01
16th May 2024

Jacobs (2024b) Pembroke Power Station Water Framework Directive Assessment Document

[6] Milford Haven Waterway Environmental Surveillance Group (mhwesg.org.uk)
[7] The Cleddau & Pembrokeshire Coastal Rivers Abstraction Licensing Strategy (cyfoethnaturiol.cymru)

JUKL/B2386202/LIC/R04
1.0
16th May 2024

Jacobs (2024c) Pembroke Power Station: Report to Inform an Appropriate Assessment (RIAA)
16th May 2024

Jacobs (2024d) Pembroke Power Station Non-Technical Summary 2023
Document no: JUKL/B2386202/LIC/R01
16th May 2024

Jacobs (2024e) Pembroke Power Station License Renewal: SSSI Assessment
JUKL/B2386202/LIC/R05
9th May 2024

Jacobs (2024f) RWE Pembroke Abstraction Supporting Information
May 2024

NRW (2023a) Consultation: Pembroke Power Station 2021 Monitoring Reports
Application Reference: DP3333TA
Drafted May 2023, Sent to RWE 13/11/2023

NRW (2023b) Letter regarding the abstraction license renewal
23rd November 2023
Reproduced in Appendix A

PML (2016) External Review of RWE Pembroke 2014 Monitoring
Plymouth Marine Laboratory
9th February 2016

RWE (2015) Pembroke Power Station Subtidal Fisheries Monitoring Proposal

NRW/HAVENMON/2015
April 2015

Appendix A: Correspondence from NRW regarding Abstraction Licence Renewal

The following is the text of a letter sent by NRW to RWE concerning the renewal and a subsequent email that provides additional detail on the Additional Information requested by NRW to support the Abstraction Licence Renewal application.

Letter from NRW Water Resources Permitting Team, 23rd November 2023

Dear All

Licence number: 22/61/60/156

Site Details: RWE Pembroke Power Station

Your water abstraction licence will end on 31/03/2025. You need to apply to renew your licence if you want to carry on taking water after this date. We will not send you any further reminders.

Any abstraction after this date would be in contravention of the Water Resources Act 1991 and will therefore be subject to enforcement action.

We strongly advise you to send us your application to renew your licence as soon as possible in order to allow for assessment of your application to be undertaken in time. At the very latest your application should be submitted a minimum of **three months** before your existing licence ends in order to be able to qualify for Licence Extension Validity (LEV). LEV is a policy applied by water resources licensing to extend the expiry date of an existing licence whilst determination of a **valid** renewal application takes place. A valid application will consist of all requested information being submitted along with your application forms; we will confirm if your submitted application is valid following initial validation checks.

For applications received before expiry of your licence, we will renew your licence if:

- your abstraction is not causing unacceptable damage to the environment;
- you can justify the amount of water you are applying for; and
- you use the abstracted water efficiently.
-

In order to support the above requirements we require the following information to be provided with your renewal application.

1. Information to demonstrate abstraction is not causing unacceptable damage to the environment.

As you are aware, your application will be assessed in accordance with the Habitats Regulations and it will be necessary to undertake an appropriate assessment (AA) as likely significant effects from the abstraction cannot be screened out. The AA will consider the impacts of the abstraction upon the features of the Pembrokeshire Marine SAC, West Wales Marine SAC, and the Afon Cleddau SAC.
The AA will include both an 'alone' assessment of impacts of the abstraction upon identified designated sites and an 'in-combination' assessment where impacts are assessed together with any relevant impacts from other plans, projects or proposals. The baseline used for the assessment will include the existing environmental conditions as affected by other already consented operations, including the existing discharge associated with the operation of the power station consented in your EPR permit (EPR/DP3333TA). In order for NRW to complete the AA you must submit the following supporting information with your renewal application;

- Details of any impacts upon fish populations, benthic organism, and the wider fish community from the abstraction and increased water temperatures (as a result of the discharge); as well as details of indirect impacts to bird or marine mammal species through prey losses, changes to food web dynamics or habitats. Please see our additional comments below in relation to this.

NRW has recently reviewed your 2021 monitoring reports submitted in association with your EPR permit requirements. My colleague Lee Mills has recently provided you with NRW's comments on these reports. You should have regard to these comments, specifically those provided on the entrapment and fish survey reports (Jacobs [2023] Quantification of Entrapment Pressure, document No: JUKL/B2386200/2021/R0; and Jacobs [2023] Pembroke Environment Monitoring Fish Survey Report 2021, document no: JUKL/B2386200/2021/R05) when collating your application supporting information. In particular, I draw your attention to the key issues highlighted in NRW's comments on the reports which I have reiterated below for clarity:

- ‘Key issue 1 - We advise that the raw entrapment data and calculations to annual estimates are clearly and transparently presented.
- Key issue 2 - We advise that sole use of the geometric mean when calculating annual entrapment is not appropriate as it leads to systematic underestimation of entrapment.
- Key issue 3 - We advise that the uncertainty/variability in entrapment estimates are presented.
- Key issue 4 - We advise that EAVs will require updating using the latest available data on, for example, mortality rates, sex ratios, fecundities and sizes/weights of entrapped fish
- Key issue 5 - We advise that post-hoc power analysis is conducted to allow us to understand the power of the monitoring programme to detect changes in the relevant fish populations and community.
- Key issue 6 - We advise that species-specific trend analysis is conducted to identify any species which may be reducing in abundance in the Milford Haven. These species could then be subject to more detailed analysis to assess whether the influence of the power station entrapment can be ruled out as causing the decline. An example of a species requiring this analysis is Atlantic herring Clupea harengus given the observed reduction in impingement.’

As well as carrying out an appropriate assessment, impacts to the Pembroke SSSI, West Wales Marine SSSI and Milford Haven Waterway SSSI will also require assessment as part of your renewal application. With regard to Milford Haven Waterway, you should submit supporting information on the impact of the abstraction upon flora and fauna of this site which could subsequently affect the bird populations feature. This includes Wintering Teal, Widgeon, Dunlin, Curlew, Shelduck and Little Grebe. Surveys and/or an analysis of existing data would assist in understanding these potential impacts.

2. Justification of quantities

You will need to demonstrate your continued need to abstract water and at the rates/quantities stipulated within your existing licence. Please include any information on why your daily and annual licensed quantities may have not been fully abstracted.

3. Use of water efficiently

You will need to demonstrate that you are abstracting efficiently; likely to be met by the use of modern technology at the station. Please provide information on any efficiency measures you implement.

You should be aware that in addition to the above information we may request further information during the determination of your application. Additional information may be required to support WFD assessment requirements, this will be requested during the determination period if it is required.

If you submit your application at least three months before your licence ends, we will only need to advertise your application if you wish to change a condition on your licence as part of the renewal application (e.g. increase the abstraction quantities).

If you send us your application less than three months before your licence ends we will not be able to determine your licence by the expiry date of your current licence.

You can get the application forms (WRA and WRD) you need from our website at Permits and permissions > Water Abstraction and Impoundment Licences > Apply for a water abstraction or impoundment licence or by calling our Customer Contact Centre on 0300 065 3000. The Customer Contact Centre will also be able to answer any questions you may have.

For information regarding fees and charges you can find all you need to know on our website at the above link. In addition to the application fee, there will be an additional charge for NRW to undertake the HRA appropriate assessment. For details of our current charges please see our website.
Your abstraction licence is subject to an annual abstraction licence charge. This is based on your full annual licensed quantity. If you no longer require this amount of water, you could take this opportunity to reduce your annual licensed quantity and therefore reduce your annual bill. But please remember, you must abstract within the licensed quantities.

Kind Regards

Water Resources Permitting Team

Email from Water Resources Permitting Team to Pembroke Power Station – 6th February 2024

Following receipt of your pre-application I have further discussed your enquiry with my marine colleagues. Further to our telephone call earlier today, I can confirm that the following data will be necessary to support your abstraction licence renewal application:

Key information/data needed to inform our advice on the HRA for the abstraction licence renewal:

1. Provision of the raw entrapment data and transparently presented calculations of annual estimates of impingement and entrainment from the raw entrapment data;
2. Provision of updated EAVs for the entrapment data;
3. Provision of annual entrapment estimates using arithmetic means rather than geometric means;
4. Provision of the uncertainty/variability in annual entrapment estimates to account for sampling resolution and scaling uncertainties;
5. Provision of species-specific trend analysis
6. Provision of post-hoc power analysis of the monitoring data.
7. Assessment of whether entrapment at the power station in-combination with increased water temperatures within the Haven as a result of the power station operation, affects populations of any fish species, the wider fish community or indirectly bird or marine mammal species through prey losses, to inform the HRA and WFD assessment. (This should be provided in the form of a shadow HRA/information to inform a WFD assessment so is a separate request really)

Regarding your questions/comments contained in your pre-application query, I have tried to address them below:

1. HRA consideration of impact of cooling water discharge. The effect of cooling water discharge forms part of the baseline/current conditions and the impact of renewing the abstraction needs to be assessed alongside this existing impact as part of the assessment in order to ensure that a robust appropriate assessment is carried out.
2. & 3. Data presentation/interpretation. Please see the points (1 to 7) set out above.
4. SSSI assessment – please can you provide further clarity on what information you are requesting – is this the format of the assessment that will be undertake, or format of how requested information should be submitted.

To confirm myself and colleagues from the marine advisory team and regulation industry team will be attending the meeting on 22nd February.

Appendix B RWE response to points raised by NRW as set out in Appendix A

The Pembroke Power Station environmental monitoring program (the Pembroke Environmental Monitoring Program) has been in place since the power station started operation in 2012; NRW conducts an annual review of the monitoring results. Since its inception, the monitoring program and the associated regulatory review processes have provided an effective framework for the scope and analysis of the Pembroke Environmental Monitoring Program to be refined as well as for NRW to review the impacts and the conclusions on the impacts of the power station. As an illustration of this, some of the points raised in the Additional Information request have previously been discussed and resolved with NRW as part of this process.

We have provided responses and context on previous discussions in the answers below but in our view, supported by the environmental experts appointed to carry out the Pembroke Environmental Monitoring Program requirements (Jacobs), these points would be best addressed as part of the monitoring programme feedback process.

For ease of reference, RWE transcribed below the Additional Information from NRW. The key issues from the original NRW letter are listed first and followed (in italics) by the version of those issues as included in NRW's subsequent clarification email. The exception to this is Issue 7, which was only listed within the email.

Key Issue 1 - **We advise that the raw entrapment data and calculations to annual estimates are clearly and transparently presented.** (*Provision of the raw entrapment data and transparently presented calculations of annual estimates of impingement and entrainment from the raw entrapment data*)

Provision of raw data

Entrapment is the term used for the combination of the aquatic life caught by a screen, which is termed impingement, and that which passes through the screen, which is termed entrainment. The Pembroke Environmental Monitoring Program surveys, that have been agreed with NRW over the years, measure both impingement and entrainment and the reporting combines the results of these individual surveys to calculate entrapment. As the entrapment is derived from two different surveys and some processing of the data is necessary to combine into entrapment there is not a single set of raw entrapment data that can be shared. However RWE has provided an excel workbook with raw entrainment and impingement data. This can be found in the document entitled Raw Entrapment Data.xlsx that accompanies this application. RWE note that raw data sets have been provided to NRW in the past.

Calculation of annual estimates from survey data

Full details of calculations made for the analysis of entrapment are provided in Appendix B of the Quantification of Entrapment Pressure report (Jacobs 2023b) with details for both the impinged and entrained fractions. The full discussion of the analysis methodology used to be in the main body of the report but was moved to the Appendix, with the agreement of NRW, to try and allow the main body to be focused and by reducing the size increase readability. The statistical approach taken is detailed in Appendix C of Jacobs (2023a) – the Fish Report. An overview of the methodology of the impingement and entrainment surveys is provided below.

The annual impingement estimates are derived from monthly averages of the impingement per unit flow. The impingement survey measures the entire all of the biota impinged on the screens over a 24hour period (8am to 8am). There are 40 impingement surveys undertaken each year. The geometric mean of the surveys in each month are calculated and then scaled to estimate the impingement given the total abstraction that occurred within the month. The method is detailed in the following figure.

Raw Abundance (main catch and trash)

Species	14/01/2019	15/01/2019	21/01/2019	22/01/2019	04/02/2019	05/02/2019	18/02/2019
Pogge	0	0	0	0	0	0	1
Lesser sandeel	0	0	0	0	0	0	0
Raitt's sandeel	0	0	1	0	0	0	0
Sandeel	0	0	0	0	0	0	0

Abundance +1 (to allow for geometric mean calculation

Species	14/01/2019	15/01/2019	21/01/2019	22/01/2019	04/02/2019	05/02/2019	18/02/2019
Pogge	1	1	1	1	1	1	2
Lesser sandeel	1	1	1	1	1	1	1
Raitt's sandeel	1	1	2	1	1	1	1
Sandeel	1	1	1	1	1	1	1

Geometric mean calculated for month (cells highlighted where greater than 1)

Species	Jan	Feb
Pogge	1	1.25992105
Lesser sandeel	1	1
Raitt's sandeel	1.189207115	1
Sandeel	1	1

False 1 returned to 0

Species	Jan	Feb
Pogge	0	1.25992105
Lesser sandeel	0	0
Raitt's sandeel	1.189207115	0
Sandeel	0	0

Abstraction data for month and typical daily figure

Total monthly abstraction (m3)	**91,099,727**	**76,792,586**
Typical daily abstraction (m3)	**2,897,333**	**2,711,444**

Factor catch to monthly abstraction (no. fish divided by typical daily flow and then scaled to monthly abstraction)

Species	Jan	Feb
Pogge	0	36
Lesser sandeel	0	0
Raitt's sandeel	37	0
Sandeel	0	0

Figure 1 Example calculation of impingement survey scaling

An additional step is required for the entrainment data as, unlike impingement, the surveys agreed with NRW do not sample the entire cooling water flow; rather a submersible pump is used to pump a sample of the water within the intake system through a fine net. It is therefore necessary to scale the observed entrainment per unit flow to the actual abstracted flow. As detailed in section B.1.3 of the Entrapment report (Jacobs 2023b) the numbers of fish and eggs recorded during each 24-hour entrainment survey are divided

by the volume of seawater sampled during the corresponding period (as determined from the flowmeter fitted to the submersible pump used to collect the sample) to calculate the number per m^3. These values were then extrapolated to 10^6 m^3 of water abstracted. This standardisation allows direct and meaningful comparison of data between surveys and sampling years. To derive extrapolated monthly entrainment estimates, if two surveys took place in a month, each survey was taken to represent half a month and abundances extrapolated to the corresponding abstraction volume. These values were then summed to give the total number of fish and eggs entrained. This has allowed entrapment (entrainment and impingement) to be assessed during these sampling months. In months where only a single survey was carried out in catches have been extrapolated to half a month using the abstraction volume for the corresponding period. These single surveys are not considered indicative of entrainment rates for the entire month, as, outside of the peak spawning season (mid-April to mid-August), entrainment declines significantly.

Similarly the impingement data, both number and mass of fish by species, are extrapolated to an annual estimate. There are a larger number of impingement surveys undertaken (40 per year) and the agreed process uses a geometric mean of the data for each month that is scaled up to the annual value using the measured cooling water flow.

The Quantification of Entrapment Pressure reports consider the loss from entrainment and impingement separately and (Section 3.1.3 Jacobs 2023b) combined as entrapment. There is extensive analysis in the reporting of the pressure of impingement and entrainment on the ecology of the estuary. The reporting includes annual losses assuming 100% mortality and site specific separation and survival rates for impingement. The significance of the loss is also explored using the Equivalent Adult Value (EAV) which is a widely used technique to evaluate pressure on spawning population as well as by comparison to dietary equivalent for a number of predator species. The impingement of invertebrates and marine flora is treated separately.

Key Issue 2 - **We advise that sole use of the geometric mean when calculating annual entrapment is not appropriate as it leads to systematic underestimation of entrapment.** (as Item 3: *Provision of annual entrapment estimates using arithmetic means rather than geometric means*)

The use of geometric means has been discussed with NRW over the years with detailed justifications also provided for the methods used in the reports included in the Pembroke Environmental Monitoring Program. For the entire duration of the environmental program, both the geometric and arithmetic means have been used when examining the fish and entrapment data (see for example Figure D-8 of the Fish Survey Report (Jacobs 2023a). The scaling of data within the entrapment report utilises both geometric (impingement) and arithmetic (entrainment) means as appropriate for the data sets.

Detail on the use of geometric means is provided in the Quantification of Entrapment Pressure report (Jacobs 2023b) Appendix B (Section B.2.3); with cross-reference to this made in the Methodology section of the main report. It is also discussed in Appendix B2 of the Fish Report (Jacobs 2023a) in which it is noted that: "*Many fish species swim in groups (schools) which are randomly distributed within the environment and fish themselves are randomly distributed within these groups. As a result, seine net, trawl and impingement catches are often not normally distributed; rather they exhibit random contagious distributions (probability distribution that exhibits a clustering effect). It is therefore*

common practice to use the geometric mean when investigating abundance and fluctuations in fish populations (Hutchings et al., 1996; ICES database). Where appropriate the geometric mean has been used to determine indices of abundance. This provides a more representative estimate of population abundance which can then be compared temporally".

RWE agreed with NRW that there was a benefit to an independent statistical review of the survey methodology. This review was commissioned by RWE and completed in 2016 by PML[8]. The intention of the review was to provide NRW with additional confidence in the assessments being undertaken in the reports included in the Pembroke Environmental Monitoring Program. RWE extended the review scope to include the structure of the reporting as well as the use of statistical techniques and tools. Commenting on the 2016 Fish Report NRW noted that they "considered the 2016 report to be a significant improvement to previous reports as advice from Paul Somerfield and NRW comments have been considered"[9] The restructured reporting (used for the 2016 annual reports and thereafter) first look for community level change, if this is detected then determine if it was ecologically significant and attributable to station operation.

Following the independent review of the monitoring program assessments confidence levels by PML, a requirement to use arithmetic means was no longer raised by NRW during their reviews of the 2016 to 2019 monitoring program.

Nevertheless, NRW further discussed the issue of geometric vs arithmetic means directly with PML in 2018. Subsequent to that discussion, NRW raised the issue directly with RWE via email (23rd August 2018). RWE's reply (email 14th September 2018) and NRW's original question are reproduced in Appendix C. The reply noted that the use of geometric means was appropriate for skewed distributions and the data was processed in line with PML's recommendations. In particular when calculating the geometric mean for each species a one was added to zero counts to avoid false zero means.

Following the email exchange NRW did not question the transformation of the raw data by use of geometric means during their reviews of the monitoring reports. However, NRW refers to the need to use arithmetic means via a request for the Additional Information, as shown in Appendix A. It is RWE's position, as informed by their experts Jacobs, that the use of geometric means to scale the impingement survey data is the proper and best scientific methodology to detect operational impacts.

Notwithstanding this, a comparison (Jacobs 2024f) of the two scaling methods has been undertaken for the purposes of the Abstraction License Renewal as requested by NRW in the Additional Information. This comparison is reproduced in italics below:

[8] Plymouth Marine Laboratory - World-leading scientific marine research (pml.ac.uk)

[9] Pembroke 2016 monitoring reports comments and meeting notes final nrw approved.pdf

Both geometric and arithmetic means were calculated and then subsequently visualised within R (R Core Team, 202[10]) utilising the tidyverse package.

Figure 2 *below shows the geometric as well as arithmetic mean of both total abundance and biomass fish (per 10^6 m^3) each month during the previous three reported monitoring years (2020 – 2022). While it is evident that both versions of the mean accurately visualise the variation in catch size throughout each year (e.g. peak abundance observed during winter months) there is a notable discrepancy between the raw values reported. The seasonal and temporal (within and between year) variations in overall impingement is not unexpected as the susceptibility of fish is strongly influenced by the abundance and distribution of species and size classes within the vicinity of the cooling water intake.*

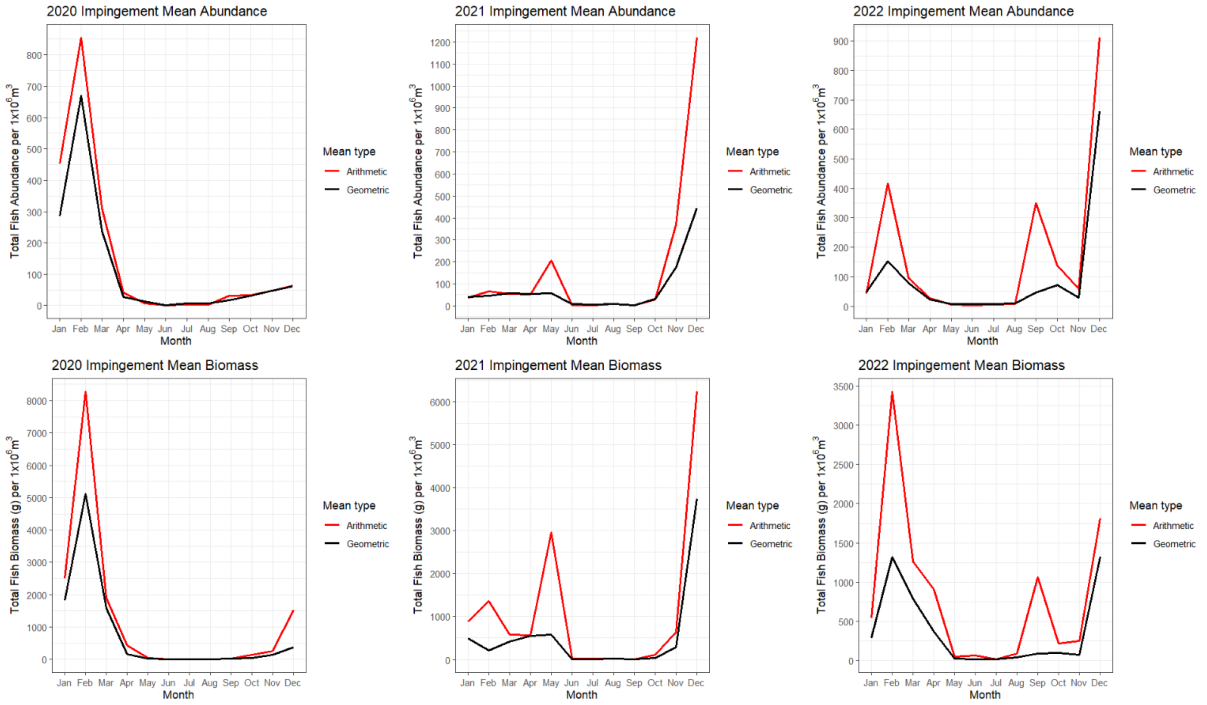


Figure 2 *The geometric and arithmetic mean of total monthly abundance and biomass recorded per 1×10⁶m³ of water abstracted during impingement surveys between 2020-2022.*

The geometric mean exhibits a far more stable behaviour, while the arithmetic are more erratic as point events influence the arithmetic mean in a greater capacity. Due to the inherent `patchy` and random nature of the impingement sampling design there is a significant chance of outlier data to be produced during surveys throughout the year – this volatility introduces skew into the data set. As a result, the overarching trend, is more accurately represented by a geometric mean.

The method adopted in the entrapment reports is to represent the 'typical' values entrapped by using the geometric mean rather than the arithmetic mean in calculations as it better represents the central tendency. It has been shown that screen-catch data has a characteristic positive skew, therefore the use of the arithmetic mean in scaling catches

[10] R Core Team. (2024). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>.

is biased (Turnpenny et. Al., 1983[11]). Furthermore many fish species swim in groups (schools) which are randomly distributed within the environment and fish themselves are randomly distributed within the groups. As a result, seine net , trawl and impingement catches are often not normally distributed, rather they exhibit random contagious distributions (probability distribution that exhibits a clustering effect). In ecology this distribution frequently occurs due to the uneven distribution of resources such as food or because of mutual attraction (e.g. fish school for protection from predators).

It is therefore common practise to use the geometric mean when investigating abundance and fluctuations in fish populations (Hutchings et al., 1983[12]). Owing to the contagious distribution of fish species observed within the impingement, intertidal as well as subtidal surveys carried out at Pembroke, where appropriate the geometric mean has been used to determine indices of abundance. This provides a more representative estimate of population abundance which can then be compared temporally.

RWE therefore remains of the opinion that the use of geometric mean is the most appropriate and best scientific method to scaling the impingement survey data obtained as part of the Pembroke Environmental Monitoring Program.

Key Issue 3 – **We advise that the uncertainty/variability in entrapment estimates are presented. (*as Item 4* Provision of the uncertainty/variability in annual entrapment estimates to account for sampling resolution and scaling uncertainties)**

NRW (2023a) provides additional detail regarding NRW's advice, which was raised during NRW's review of Appendix D of Jacobs (2023b), *"We advise that uncertainty estimates/percentiles around these entrainment and impingement data are needed to capture the variability in the impingement rates. Bootstrapping the raw data could achieve this."*

As noted previously, the Pembroke Environmental Monitoring survey program and analysis methodology were both agreed with NRW and have evolved over the life of the station to meet NRW's requirements. An independent review by PML of the analysis and reporting was commissioned RWE and the feedback incorporated in the 2016 and subsequent reports. NRW acknowledged the improvement in the reporting resulting from these changes in their review of the 2016 reporting**.**

The number of agreed samples taken during the impingement and entrainment surveys are detailed below:

- **Impingement**: In 2012 there were fifteen impingement surveys with a focus on the early part of the year. From 2013 onwards forty 24 hours samples have been taken with twenty two of these in the spring and summer seasons.

- **Entrainment**: There has been a greater change in the number and timing of entrainment surveys carried out since 2012 with additional surveys being added to better capture the peak in entrainment. In 2012 there were eleven 24 hour

[11] Turnpenny, A.W.H., Utting, N.J., Milner, R.S. and Riley, J.D. (1983). The effect of fish impingement at Sizewell A Power Station, Suffolk, on North Sea fish stocks. Central Electricity Generating Board, Sizewell Public Inquiry Support Document No. TPRD/L/3270/R88, 28 pp.

[12] Hutchings, J.A. (1996). Spatial and temporal variation in the density of northern cod and a review of hypotheses for the stock's collapse. Canadian Journal of Fisheries and Aquatic Science. 53, 943 – 962.

entrainment surveys carried out throughout the year, with sampling focussed during the summer months (two surveys carried out in each of May, June and July) when ichthyoplankton abundance within the Haven is at its highest. Entrainment was found to peak between May and July, with extremely low entrainment observed between late summer and early spring inclusive. Subsequent monitoring was therefore targeted to capture peak entrainment of fish larvae in 2013 & 2014 six 24 hour samples were carried out with two in each of May, June & July. In 2015 two additional surveys were included with one in late April and one in early August. This sampling protocol continued until 2020 when an additional sample was added in early April for a total of nine.

The method used to scale up the survey data to estimate the total impingement at Pembroke Power Station is provided in detail within the annual reports included in the Pembroke Environmental Monitoring Program. The estimated annual entrapment will reflect the ability of the survey to capture the variability in impingement and entrainment. Overall entrapment can be expected to vary due to the natural variability in the numbers of fish within the vicinity of the power station intake both within and between years. The agreed surveys include intertidal and sub tidal monitoring and the reporting incorporates data from other sources to provide context to the observed entrapment.

It has been suggested by NRW that bootstrapping the data may be a means to understand the uncertainty in the annual entrainment & impingement data. It is important to note the variation between years, this is illustrated by the following figure from the 2021 Entrapment Report (Jacobs 2023b) which shows the geometric monthly mean number of impinged sprat, sand smelt and poor cod impinged each month between 2012 and 2021. While there is a common trend in the variation of numbers by month, with all years showing a U shaped variation between January and December, the actual numbers will vary between years by up to three orders of magnitude.

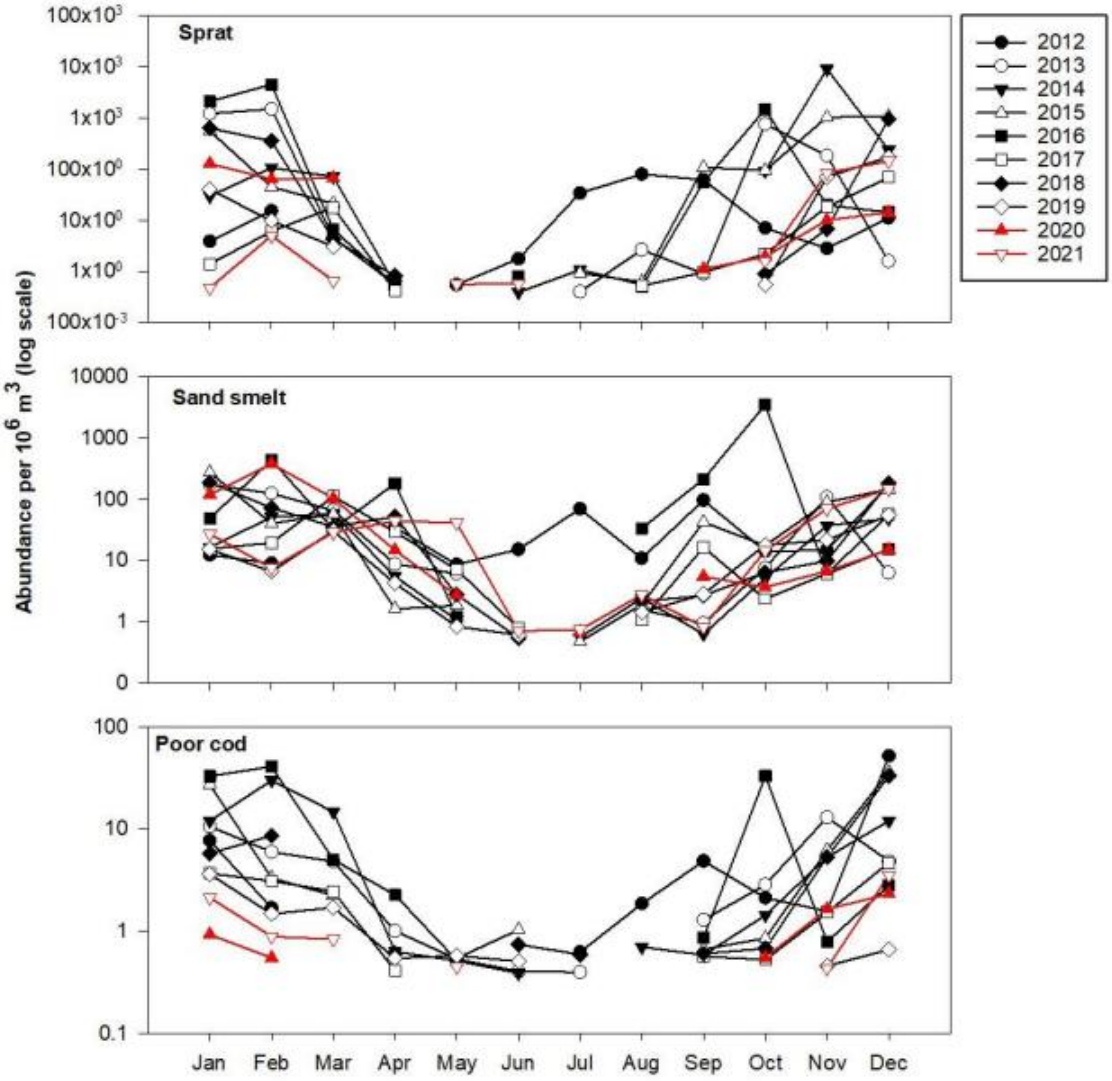


Figure 3 Geometric mean monthly abundance (per 10^6 m^3) of sprat, sand smelt and poor cod which each contributed > 1% to the total abundance impinged between 2012 and 2021 combined (Figure 3 of Jacobs 2023b)

Samples taken over time exhibit temporal autocorrelation, due to the underlying natural interannual variability and seasonal patterns. Consequently, pooling samples from multiple years in order to estimate the uncertainty in a single year's impingement would violate the necessary assumption that observations in the bootstrapped dataset are independent and identically distributed.

To overcome this limitation, bootstrapping was used to generate simulated datasets by resampling data collected within a single year, thereby accounting for natural interannual variability. Additionally, resampling was applied to each month independently to address intrinsic temporal autocorrelation. Specifically:

- For each month of the year, three simulated datasets were produced using alternative procedures to resample the measurements collected within that specific month. All procedures involved resampling with replacement, assigning equal probability to each original data point. Each month was treated independently, and the additional assumptions were as follows:
    1. Each replication comprised a single value, randomly sampled from the measurements available within that month.
    2. Each replication consisted of two values, randomly sampled with replacement from the measurements within that month.

3. Each replication contained a number of values identical to those in the original dataset, all randomly sampled with replacement from the measurements available within that month.

- Geometric means were than calculated from the resampled data for each month, and these means were summed to obtain estimates for the annual impact. Before calculating the geometric mean any zero counts were replaced with 1.

One thousand replications were generated for each of these three resampled datasets. The diverse combinations of values in the simulated samples collectively provide an estimate of the variability between random samples drawn from the original data points, which serve as a proxy for the real population. This approach enables the inference of the inherent uncertainty in the collected data and its implications for the power of the sampling protocol.

The results of the bootstrapping exercise for the species plotted in Figure 4 are shown below, utilising the 2023 monitoring dataset for illustration.

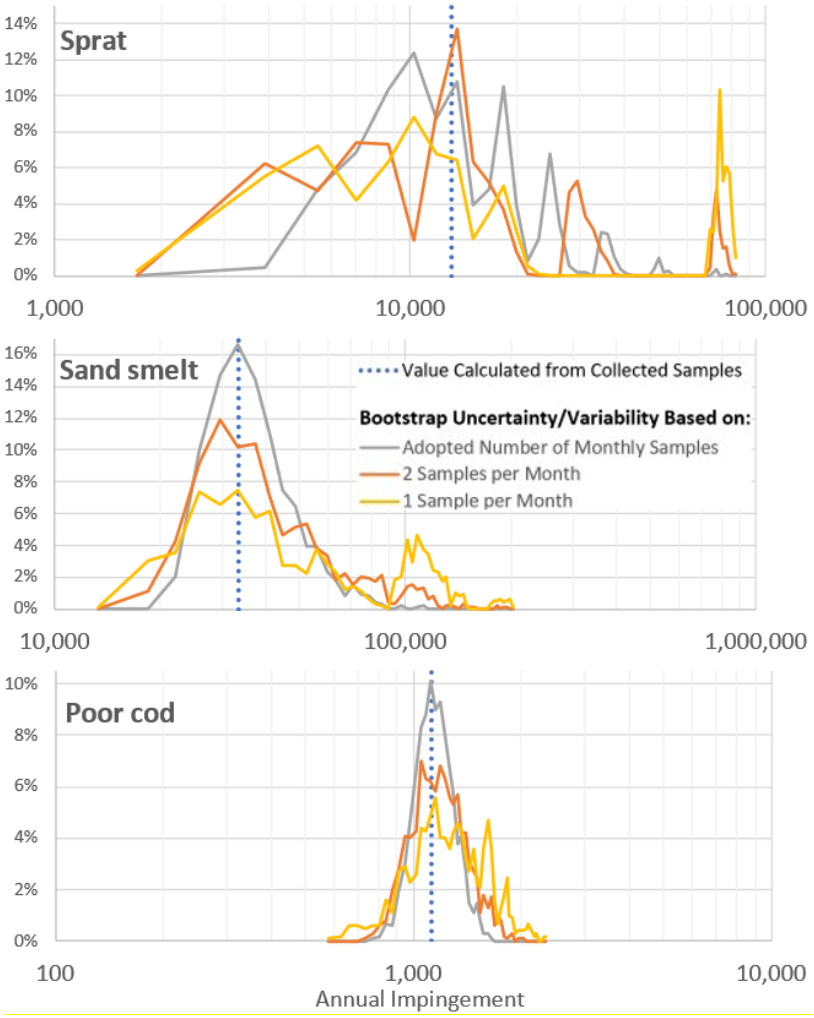


Figure 4: bootstrap analysis results of 2023 monitored samples. The charts illustrate the distribution of the annual figures for impinged fish (sprat, sand smelt and poor cod), derived from an ensemble of bootstrap replications. Vertical dotted lines represent the values inferred by using the complete dataset of monitored data. The three curves illustrate the variability of the bootstrap population for: one-sample random extraction per month (yellow curves), two-sample random extraction with replication per month (orange curves), and a number of samples equivalent to the ones in the original dataset, randomly extracted with replication per month (grey curve).

The results in Figure 4 show how bootstrap uncertainty is distributed around the value derived from analysing the entire dataset of monitored data. The largest variation, observed for 'sprat', primarily stems from the distribution of the samples monitored in 2023, with most values showing zero or very low numbers, while two 24-hours samples exhibit outlying values. In contrast, the uncertainty range tends to be considerably smaller for 'poor cod', for which the 2023 monitoring campaign resulted in a larger number of samples showing finite and more uniformly distributed values.

It's also worth noting how the bootstrapped uncertainty tends to decrease and the tails to narrow with an increase in the number of samples, from 12 (one per month, yellow curves) to 24 (two per month, orange curves), to 40 (sampling protocol).

The bootstrap method presented here has been applied to explore its use in estimating uncertainty in the entrapment data. It must be noted that the monthly resolution of data does not truly lend itself to the bootstrap method owing to the number of samples in each month. There are no universal rules for the minimum (real observations) sample size in order to bootstrap, however there are recommended guidelines. Efron and Tibshirani (1993)[13] report that the bootstrap tends to work well when the sample size is at least 30 and Wu (1986)[14] recommend a sample size of at least 50 to 60 for estimating standard errors. The issue with small sample sizes is that the bootstrap samples will frequently consist of repetitions of the same sample combinations, making it difficult to accurately measure variability and estimate uncertainty.

Lastly, it is important to emphasize the prominent role of natural interannual variability, as illustrated in Figure 3. This exogeneous driver, independent of the operational pattern of Pembroke power station, tends to exert a dominant influence on the overall uncertainty in the annual results.

A similar conclusion also applies to an analysis of the entrainment data. In this case, bootstrap techniques were used to assess the impacts of a scenario where only one monthly sample was collected (by randomly selecting one of the two samples collected in months when two samples were available). The analysis focussed on the 'Sand Smelt' and 'Goby' families, for which entrainment tends to occur throughout most of the monitored period. As with the impingement data, the results indicate that natural interannual variability is the primary source of overall uncertainty in the inferred annual results.

In addition to the short and long term variability in the populations potentially in the vicinity of the intake and therefore at risk of entrapment there are other abiotic factors that could play a role. These include the potential influence of tides and wind as well as the intake flow over the sampling period.

Jacobs have undertaken a multivariate analysis of the influence of a range of abiotic factors on the impingement data. The study therefore contributes to an understanding of the uncertainty in the sampling program and the findings are outlined below.

[13] Efron, B., & Tibshirani, R. J. (1993). An Introduction to the Bootstrap
[14] Wu, C. F. J. (1986). Jackknife, bootstrap and other resampling methods in regression analysis.

The study used a non-parametric Global BEST[15] procedure which was also recommended by NRW[16] and was undertaken using the Primer 7 software package. The study examined the following abiotic factors:

- CW flow rate;
- Intake temperature;
- Average wind speed on survey days;
- Average wind direction on survey days;
- Average wind speed two days prior to the survey;
- Average wind direction two days prior to the survey;
- Maximum tidal range recorded during the survey.

The results of the BEST procedure showed that the between year variability in impingement abundance and biomass was driven mainly by sea temperature resulting from seasonal variations. Temperature was considered to be a proxy for the time of year which explains a significant proportion of the variation in impingement. The BEST procedure showed that the variability in impingement was not significantly correlated to any of the other abiotic variables tested either in isolation or combination. This provides confidence that the sampling program is not limited by the range of wind, tide and CW conditions being sampled.

In conclusion bootstrapping has been used to study the uncertainty in annual impingement that arises from the agreed program of forty twenty four hour surveys. The uncertainty in annual estimate varies between species with lower uncertainty for species with more evenly distributed numbers (as shown by the difference seen in Figure 4 for poor cod and smelt). The bootstrapping is an addition to a previous study of the factors influencing impingement which provided confidence that the sampling program is not limited by the range of wind, tide and CW conditions being sampled.

We also note that (Jacobs 2024f) the *"annual reports provided across the monitoring programme include confidence intervals on the graphics to show the levels of variability in the data points provided. This was introduced following consultation with NRW who felt that an understanding of the variability was needed when interpreting the data. Whilst the uncertainty is not provided in the extrapolated abundance data, it is provided in the analysis that is used to assess entrapment pressure. There will be inherent uncertainty in the scaling of the entrapment data as assumptions are made (as agreed with NRW previously) when the data are scaled. The fundamental point here is that regardless of the scaling method, the data are showing no significant effects at the community level, therefore the conclusion relating to no effect on the conservation objectives of the SAC remain".*

[15] Testing of null hypotheses in exploratory community analyses: similarity profiles and biota-environment linkage (pelagicos.net)
[16] Jacobs (2019) Pembroke Power Station Fish Report 2018_memo

Key Issue 4 – **We advise that EAVs will require updating using the latest available data on, for example, mortality rates, sex ratios, fecundities and sizes/weights of entrapped fish.** (*as Item 2 Provision of updated EAVs for the entrapment data*)

It is acknowledged that updated information may be available for the life histories of fish species assessed. RWE commissioned as part of the Pembroke Environmental Monitoring Program the creation of dedicated life tables specific to the Celtic Sea for the purpose of supporting the assessment of entrapment using sound science including sensitivity analysis. These tables were peer reviewed and used with other Irish Sea developments. RWE has recently commissioned from Jacobs a review of data published after the bespoke Celtic Sea life tables were produced in order to judge if new EAV tables are possible or necessary (Jacobs 2024f); this included a sensitivity analysis for herring as a species of interest.

The review found that that much of the more recent data (where they are available) are within the range of those utilised within the Pembroke lifetables. Where differences were noted it was noted that "*some parameters are expected to change annually. e.g., fishing mortality, some data may be less relevant/reliable (e.g. laboratory-derived vs environmental) and average values for some parameters have been used in the original lifetables so even though the more recent literature may indicate values would be different, the overall lifetable and EAV outputs are not expected to change the magnitude of calculated annual adult equivalents".*

In conclusion the Jacobs literature review did not find new data that invalidated the life tables developed specifically for the location of Pembroke Power Station.

Full information can be found in the 2024 Pembroke Abstraction Supporting Information report (Jacobs 2024f).

Key issue 5 – **We advise that post-hoc power analysis is conducted to allow us to understand the power of the monitoring programme to detect changes in the relevant fish populations and community.** (*Provision of post-hoc power analysis of the monitoring data*)

Post-hoc power analysis has previously been discussed with NRW and was agreed not to add value to the ongoing environmental reporting. Some historic context to the Pembroke Environmental Monitoring Program and use of statistics is provided in the following paragraphs.

In 2013 RWE received a letter from NRW (Pembroke Power Station Rationale for the removal of subtidal fish monitoring from the 2014 monitoring programme. (Advice from NRW to RWE nPower 18th December 2013) stating that they felt that the subtidal fish programme should be removed from the monitoring programme because it was believed that it did not have the statistical power to detect changes with reasonable certainty of a scale relevant to the SAC's conservation objectives, nor have the ability to attribute these changes to the operation of Pembroke Power Station. Furthermore, NRW did not believe that the benefits gained from these surveys outweighed the damage caused to the seabed east of Milford Haven, where the use of mobile benthic fishing gear is otherwise not permitted. In the letter NRW specifically raised the issue of the statistical power of the surveys and the lack of an analysis of the analytical power to determine what level of significant change can be detected with existing levels of effort.

RWE responded (RWE 2015) in the form of a report which drew on a number of memos previously issued to NRW. The report summarises the history of the monitoring and the

expansion in the number of subtidal trawls as requested by EA Wales in consultation with CCW NRW in 2012. In 2013 & 2015 NRW requested a reduction in the number of sites which reduced the total back to the number (thirteen) used at the start of surveys in 2006.

RWE recommended the retention of the sub tidal surveys to *"provide post-commissioning data on which community level change can be examined. Once sufficient post-commissioning data has been collected the potential for rationalisation can be considered using scientific evidence to support the future approach and programme"*.

Specifically regarding post-hoc power analysis RWE noted that *"discussions between NRW, RWE and Jacobs have also focused on the usefulness of retrospective power analysis. This approach of using the data to determine the power of a test after the data have been collected (rather than using it to design a future independent study i.e. a priori power analysis) is considered to be fundamentally flawed as it is inappropriate to calculate power using the effect size obtained from the data in a retrospective power analysis. Retrospective power analysis is an improper calculation of a probability and it cannot be used to add something to the interpretation of the results"*.

RWE's proposal was to reduce the sub tidal trawl to every other year. This halved the impact which was of concern to NRW whilst allowing the survey program to continue albeit with reduced temporal resolution. RWE requested that "*as a pre-requisite to this reduction agreement, NRW should confirm their agreement that the modified program fulfils Permit Condition PO4a. In particular RWE requires sufficient comfort from NRW that there will be no further review of the power of the monitoring program"*.

In 2015 NRW wrote to the Welsh Government to provide their opinion on the 2014 reporting. This report states that the *"Appropriate Assessments (AA) produced by the Environment Agency concluded that no adverse impact would be seen on the features of the SAC as a whole. As of November 2015 this conclusion continues to be supported by the monitoring results"*.

RWE commissioned an independent review of the use of statistics in the reporting of the survey data. This study (PML 2016) reviewed the 2014 reporting and concluded that:

> *"The overall program appears appropriate for the monitoring of the ecological effects of the power station within the SAC. No major detrimental effect of the installation, or operation, of the power station on the ecology of the SAC is apparent in the reports reviewed"*.

A number of suggestions for the improvement of the reporting were made by PML which were implemented in the 2016 reports.

In response to the request for additional information RWE has commissioned (Jacobs 2024f) to undertake a study of the ability of the monitoring program to detect change in fish populations. This is reproduced in italics below:

"The observed or post-hoc statistical power is based on the effect size estimate derived from a dataset. As observed power differs from the true power of a sampling design to detect a significant effect using it as a tool to indicate power for outcomes already observed is not only conceptually flawed but also analytically misleading (Zhang et al, 2019[17]). Low power will likely be indicated from results concluding non-significant effects

[17] Zhang Y, Hedo R, Rivera A, Rull R, Richardson S, Tu XM. (2019). Post hoc power analysis: is it an informative and meaningful analysis? Gen Psychiatry 32(4).

(Hoeing & Hiesey, 2001[18]) undermining the ability to detect true negatives (concluding there is no effect, when there is no effect) from false negatives (concluding there is no effect, when there actually is an effect, or a Type II error). Therefore, a comprehensive simulation-based power analysis (following Weiser et al, 2021[19]) was conducted to determine the estimated power of each data set / sampling design to detect change in abundance across a range of annual trends.

Abundance data from the previous ten years of impingement, as well as subtidal and intertidal fisheries was utilised in the calculation of the key metrics (as per Weiser et al, 2021) that were subsequently input into the TrendPowerTool (https://rconnect.usgs.gov/TrendPowerTool/). The outputs, of which, provide estimates on the ability of each data set to detect varying levels of annual change. Raw abundance was pooled by survey for impingement, by site for intertidal fisheries, and Catch per Unit Effort (CPUE) was pooled per site for subtidal fisheries. Each of the 40 annual impingement surveys were treated as an individual site.

1. Impingement

The estimated statistical power of the impingement dataset increases with increasing annual change (Figure 5). Effectively, the data set can detect an inter-annual change in the populations between 7.5%-10% with an estimated power of 0.8, detecting a lower percentage change in abundance diminishes the estimated power. In order for the sampling design to produce a dataset that could detect smaller annual variation (at acceptable power values, ≥0.8) in population trend, an increase in the number of individual surveys would be required. For instance, the model estimated that 200 surveys (per year over 10 years) would need to be conducted per annum (currently 40) in order to detect an annual change in abundance of 3% with a power ≥0.8.

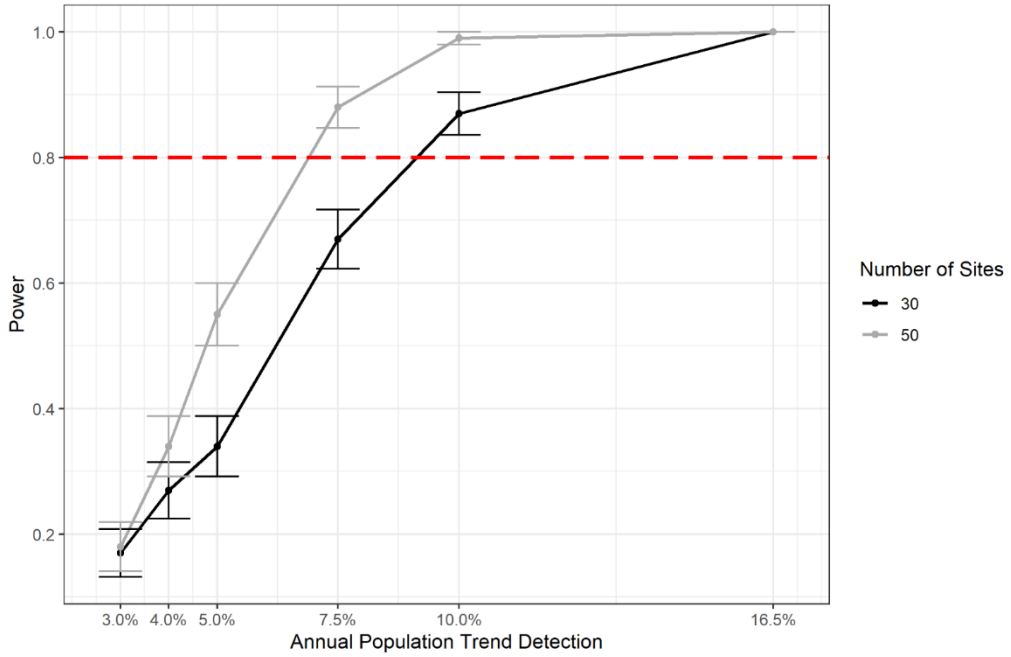


Figure 5 ***Estimated statistical power of the last ten years of impingement data to detect population change. The TrendPowerTool estimates power for either 30 or 50 sites annually, as 40 impingement surveys are conducted a year both are displayed. Error bars represent the standard error of the estimated power.***

[18] Hoenig J. M., and Heisey, D. M. (2001). 'The Abuse of Power: The Pervasive Fallacy of Power Calculations for Data Analysis', The American Statistician, 55(1), pp. 19–24.

[19] Weiser E.L., Diffendorfer J.E., Lopez-Hoffman L., Semmens D., Thogmartin W.E. (2021). TrendPowerTool: A lookup tool for estimating the statistical power of a monitoring program to detect population trends. Conservation Science and Practice.

2. *Subtidal and Intertidal Fisheries*

The sampling design of both the subtidal and intertidal fisheries surveys are sufficient to detect an 7.5% change in abundance (CPUE in the case of subtidal fisheries) per annum (Figure 3). Similar to the Impingement dataset, the lower the variation in the abundance the lower the estimated power values. The model estimated that 200 sites (per year over 10 years) would be required to be surveyed per annum (currently 28) for both the subtidal and intertidal fisheries sampling design to support a detection of 3% change per annum with a power ≥0.8.

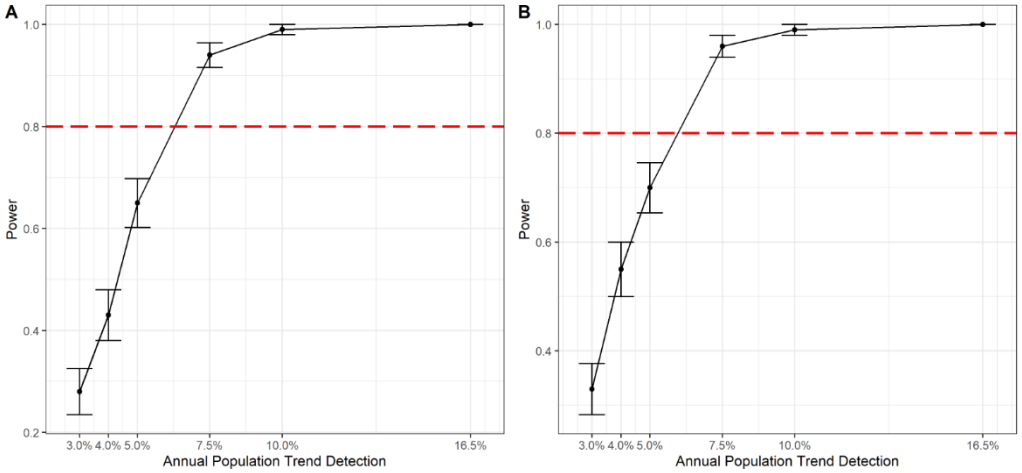


Figure 6 Estimated statistical power of the last ten years (2013-2022) of both the subtidal (A) as well as intertidal (B) fisheries datasets to detect population change. Error bars represent the standard error of the estimated power.

The study concluded that: *Power is usually desired to be at least 0.8 (Cohen, 1988[20]; Stefano, 2003[21]), although values of power as low as 0.5 are sometimes considered acceptable (Murphy and Myors 2004[22]). In practice, it is often difficult to obtain power much greater than 0.8 (i.e., a very large sample size is necessary) (Morrison, 2007[23]). The impingement, subtidal and intertidal fisheries data sets all support a detection of 7.5%-10% change in the abundance per annum at an estimated power ≥0.8. The current sampling regime has been agreed with NRW and is able to confidently detect acceptable levels of change (7.5-10% per annum) to reach a robust and reliable decision in this case".*

[20] Cohen, J. (1988). Statistical Power Analysis for the Behavioral Sciences. Lawrence-Erlbaum. Hillsdale, N.J.
[21] Stefano, J. D. (2003). How much power is enough? Against the development of an arbitrary convention for statistical power calculations. Functional Ecology 17:707–709.
[22] Murphy, K. R. and Myors, B. (2004). Statistical Power Analysis: a Simple and General Model for Traditional and Modern Hypothesis Tests. Lawrence Erlbaum. Mahwah, N.J.
[23] Morrison, L. W. (2007). "Assessing the Reliability of Ecological Monitoring Data: Power Analysis and Alternative Approaches," Natural Areas Journal 27(1), 83-91.

Key Issue 6 – **We advise that species-specific trend analysis is conducted to identify any species which may be reducing in abundance in the Milford Haven. These species could then be subject to more detailed analysis to assess whether the influence of the power station entrapment can be ruled out as causing the decline. An example of a species requiring this analysis is Atlantic herring Clupea harengus given the observed reduction in impingement.** (*as item 5 Provision of species-specific trend analysis*)

Again RWE note that the monitoring program and reporting has evolved over the life time of the program to reflect NRW's concerns. The reporting draws on the monitoring program and other data sources to put the observations into context. This is discussed further in Jacobs (2024f) – which is reproduced in italics below.

"*Within the fish and entrapment pressure reports, focus is given to individual species of concern, and this reflects the data being analysed as well as focus areas for NRW. These species are reviewed in terms of trends in annual abundance and are provided for all years of monitoring so shifts in abundance can be seen. More detailed analyses of individual fish species is provided in the annual fish report, again with the focus on species being driven by what is seen in the data.*

Species reviewed include the following:

- *Sprat;*
- *Sand smelt;*
- *Gobies;*
- *Herring;*
- *Bass;*
- *Lesser-spotted dogfish;*
- *Gadoids; and*
- *EPAA species*

Examples of the analysis contained in the reports are shown in Figure 4 above for sprat, sand smelt and poor cod. The analysis of trends in abundance for the species of concern are within Section 5 of the Entrapment Pressure report with wider analysis of the species within the fish report. The trends in mean monthly abundance of key species are plotted cumulatively in each of the Entrapment Pressure reports allowing any trends to be visualised. See for example Figure 3 of the 2021 report (Jacobs 2023b) which is reproduced as Figure 3 above.

The annual reports acknowledge that species populations, including fish communities, within the Haven vary in time and space, partly in reflection of the variable habitats and dynamic environment of the estuary; stochastic events and the great variation in survival and recruitment of species also plays a major role (NRW, 2017[24]). As such, 'boom and bust' species such as sprat and sand smelt have demonstrated dramatic increases and decreases during the monitoring programme as a result of natural variability in environmental factors, spawning and recruitment success and other factors relating to their population dynamics. Equally, species that are infrequently recorded may disappear altogether for a period of time, whilst new ones might arrive in the Haven particularly as species ranges extend northwards as a result of climate change. Importantly, it is expected to see short-term changes to the fish communities within Milford Haven, but it is the relative long-term stability (e.g. cyclical patterns) and persistence of species

[24] Natural Resources Wales (2017). Pembrokeshire Marine / Sir Benfro Forol Special Area of Conservation. Advice provided by Natural Resources Wales in fulfilment of Regulation 35 of the Conservation of Habitats and Species Regulations 2010 (as amended). Cardiff, Wales. 131 pp. [Online]. Available at: https://naturalresources.wales/media/682013/pembrokeshire-marine-reg-35-report.pdf [Accessed March 2018].

populations and functional guilds that should inform any assessment of the impacts of any pressure of which power station operation is one".

In summary it was concluded that "*the observed changes in fish communities remain in line with expected variation, based upon the knowledge from previous years, as well as from historical data, unpublished data from NRW fish monitoring and general appreciation of the complex estuarine fish community dynamics in the Pembrokeshire Marine SAC. There is no evidence to date of an ecologically significant change in the fish community since monitoring began, in terms of abundance or diversity of the core species".*

Key Issue 7 *Assessment of whether entrapment at the power station in-combination with increased water temperatures within the Haven as a result of the power station operation, affects populations of any fish species, the wider fish community or indirectly bird or marine mammal species through prey losses, to inform the HRA and WFD assessment. (This should be provided in the form of a shadow HRA/information to inform a WFD assessment so is a separate request really)*

It is noted that NRW in correspondence has required that the impacts of the renewal licence be considered in combination with the increased water temperature within the Haven as a result of the power station discharge. The applicant does not consider that such consideration is typically required for an abstraction license but has nevertheless it has set out its assessment of those effects.

As outlined in section 5.4 and 9.1 of the Report to Inform and Appropriate Assessment (Jacobs 2024c) the baseline data on which the assessment has been made already inherently captures the effects of station operation, specifically temperature. The operation of the station is regulated as part of the Environmental Permit, for which annual reports are prepared and discussed. None of these reports have indicated an effect on fish populations from increased temperature and the abstraction with the main community composition remaining stable.

SSSI Assessment

In addition to the "Key Issues" listed NRW (NRW 2023b) the letter included a requirement to undertake an assessment of the SSSI. "*As well as carrying out an appropriate assessment, impacts to the Pembroke SSSI, West Wales Marine SSSI and Milford Haven Waterway SSSI will also require assessment as part of your renewal application. With regard to Milford Haven Waterway, you should submit supporting information on the impact of the abstraction upon flora and fauna of this site which could subsequently affect the bird populations feature. This includes Wintering Teal, Widgeon, Dunlin, Curlew, Shelduck and Little Grebe. Surveys and/or an analysis of existing data would assist in understanding these potential impacts".*

An assessment has been undertaken (Jacobs 2024e), this noted that "*Milford Haven is one of the most studied areas of water with extensive monitoring undertaken by RWE as part of Power Station operations as well as routine water framework directive monitoring undertaken by Natural Resources Wales".* This extensive monitoring program includes the operation of the power station and hence any potential influence of the thermal discharge.

The conclusions of the SSSI assessment are included below:

- *Pembroke Power Station has been operational since 2012, abstracting sea water from the western Pennar Gut at the mouth of the Pembroke River.*
- *The Milford Haven Waterway SSSI covers a wide range of habitats and species from the estuary mouth to the tidal limits on the Cleddau, Pembroke River and a number of other significant embayments and inlets.*
- *Of the marine features cited on the SSSI citation, a number of habitats and species are not reported from the Pembroke River or southern Milford Haven shoreline, those being the areas of the SSSI with a potential pathway to effect from abstraction:*
    - *Not reported within Pembroke River/south Milford Haven shoreline– caves and overhangs, moderately exposed rock and sand, rockpools, silled saline lagoons, tide swept algae, under boulders, European smelt, tentacled lagoon worm, Gammarus chevreuxi*
    - *Reported within the Pembroke River but outside of the zone of influence of the abstraction – mixed substrata, muddy gravel, eelgrass, saltmarsh, otter.*
- *Sheltered rock and sheltered mud are SSSI habitats recorded within the zone of influence of the abstraction. Both of these habitats have been identified as stable over the period of operation of the power station operation, and are therefore resilient to local scale changes in water velocity brought about by abstraction. It is considered likely that tidal action in these areas are more significant to the functioning of these habitats than abstraction pressure.*
- *Teal, wigeon, dunlin, curlew, little grebe and shelduck have all been reported from Milford Haven. These species utilise a variety of marine, freshwater and terrestrial habitats at different stages of their respective life cycles. The area of effect is considered to be high localised to the abstraction intake and represents a fraction of the available habitat available to waterfowl in the wider Pembroke River and Milford Haven Waterway. Furthermore it is considered unlikely that water fowl would preferentially target feeding and roosting habitat in close proximity to the relatively industrialised western end of Pennar Gut when large expanses of the wider estuary, inlets and embayments provide area of lower disturbance and shelter.*
- *Habitat loss for those species preferentially using mudflats and other maritime wetland areas has been shown to be negligible as a result of abstraction. Therefore there is no pathway to effect from habitat loss on water fowl from the abstraction.*
- *The Power Station abstraction does entrap a range of fish species, marine invertebrate and aquatic flora/macroalgae that represents a potential food source for cited water fowl. Studies undertaken to quantify and contextualise marine faunal and flora loss through abstraction has demonstrated no observable difference in fish or invertebrate populations in Pennar Gut during the operation of the Power Station. This indicates there is no pathway to effect from abstraction from the loss of prey items to cited water fowl.*
- *There are no predicted effects on SSSI species cited in the Milford Haven Waterways SSSI from the continued abstraction of water at Pembroke Power Station.*

Appendix C Correspondence regarding scaling of impingement data

From: NRW to RWE Pembroke Power Station

Subject: Geometric Mean Comment 2016 reports

This is the comment mentioned on the phone regarding the geometric mean which was too late to share for the 2017 reports but I forward for your information.

Use of geometric mean: NRW sought advice from Bob Clarke from Plymouth Marine Lab on the use of geometric mean:

"*I would have doubts about the use of a geometric mean, for the simple reason that it is strongly biasing towards zero. As you suggest, the geometric mean – and also the even more extreme harmonic mean (which takes the means of the reciprocals of the values and then the reciprocal of that) – always give values smaller than the arithmetic mean. For a right-skewed continuous (and always positive) distribution this can sometimes be sensible…*"

Bob Clarke suggests that maybe the consultant added 1 to 0 counts before calculating the geometric means, which would be a more correct approach for this geometric mean calculation. In the reports (last year) it states that the geometric mean for fish impinged each month was calculated. Was this undertaken ?

Overall, Bob Clarke advises the use of PRIMER to transform the data, e.g. by square root or 4^{th} root transform, depending on how strongly right-skewed the counts are, before calculating the arithmetic mean. In other words, the transform is chosen to make the distribution somewhat more symmetrical and then an arithmetic mean is always the most efficient way of describing its centre.

Could these considerations please be taken into account for the fish entrapment reports.

Regards

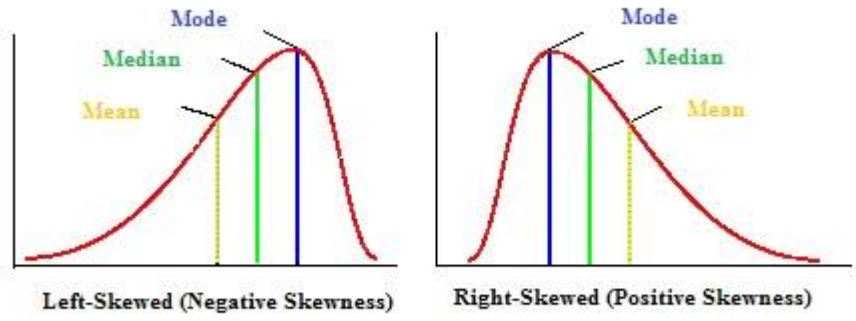
Reply from RWE to NRW

We have discussed the comments below made by Bob Clarke and passed to us by yourselves regarding the use of geometric mean, and make the following response.

The impingement data do indeed have a right-skewed/positive distribution; this is a distribution that is skewed to the right (that is, bunched up toward the left and with a "tail" stretching toward the right) as there are few zero catches, a lot of low catches and few really high catches in any one year. The degree of skew in any one year is variable but has never been normal or left-skewed. As Bob Clarke states below "for a right-skewed continuous (and always positive) distribution this can sometimes be sensible…".

In our response to NRW's 2016 report comments we stated that "It has been shown that screen-catch data has a characteristic positive skew, therefore the use of the arithmetic mean in scaling catches is biased (Turnpenny et. Al., 1983)". This is because when data distribution is right-skewed the arithmetic mean is always higher than the mode (which represents the value that appears most often or that is most likely to be sampled) and higher than the median (which again represents a more typical value).

This is illustrated in the figure below.



As per Bob Clarke's recommendations we have indeed always added 1 to 0 counts before calculating the geometric means.

Mathematically, the geometric mean is the equivalent of taking the arithmetic mean of log transformed data. So in theory, we are already undertaking a transformation of the data as Bob Clarke recommends and then calculating the arithmetic mean. Subsequently, the question would be whether a less severe transformation would be more appropriate (e.g. square root or fourth root); however, the log transformation would be considered appropriate due to the degree of skewness of the impingement data in most years.

Therefore we feel that Bob Clarke's recommendations are consistent with the approach we are taking, in that:

- It is sensible to use the geometric mean for a right-skewed continuous (and always positive) distribution
- A 1 is added to 0 zero counts prior to calculating the geometric mean
- The data is transformed prior to calculating the arithmetic mean to a suitable level based on how strongly right-skewed the counts are (geometric mean is the equivalent of taking the arithmetic mean of log transformed data)

I hope this is helpful. Please get in touch if you want to discuss it.
Regards