Renewal of Pembroke Power Station Abstraction License: Estimation of Entrapment Uncertainty

Reference Number: ENV/753/2024
Date: 10/12/2024
Issue: 1

This document is supplied on and subject to the terms and conditions of the Contractual Agreement relating to this work, under which this document has been supplied, in particular:

Confidentiality
This document is unrestricted.

Liability
In preparation of this document RWE Generation UK plc has made reasonable efforts to ensure that the content is accurate, up to date and complete for the purpose for which it was contracted. RWE Generation UK plc makes no warranty as to the accuracy or completeness of material supplied by the client or their agent. Other than any liability on RWE Generation UK plc detailed in the contracts between the parties for this work RWE Generation UK plc shall have no liability for any loss, damage, injury, claim, expense, cost or other consequence arising as a result of use or reliance upon any information contained in or omitted from this document.

Any persons intending to use this document should satisfy themselves as to its applicability for their intended purpose.

The user of this document has the obligation to employ safe working practices for any activities referred to and to adopt specific practices appropriate to local conditions.

Renewal of Pembroke Power Abstraction License: Estimation of Entrapment Uncertainty

Prepared by:
Andrew Moores,
Kevin Thatcher

Reviewed by:	**Authorised by:**
Gill Hunter	
Adriana Gasparini	Roland Long

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).

Specifically, this report provides the uncertainty estimate for the annual entrapment as required by NRW. In an email dated the 16th July 2024 NRW confirmed validation of the renewal application (PAN-025790) and requested further information. This included, in addition to other requirements supplied separately, a request for an assessment of uncertainty as follows:

- *"Provision of the uncertainty/variability in annual entrapment estimates to account for sampling resolution and scaling uncertainties – bootstrapping process to apply for all species".*

This was further clarified in an email from NRW on 28th August which stated:

- "*conducting 40x24hr impingement samples each year gives temporal coverage of ~11%. Extrapolating this to 100% temporal coverage for a year introduces uncertainty and potential variability that needs to be explored and understood to account for it in the assessment. Furthermore, any averaging of entrapment or flow data during the process to calculate annual entrapment figures also introduces uncertainty and potential variability."*

The uncertainty estimate reported herein was obtained using a bootstrap of the sample data following the method used by EDF to obtain an uncertainty estimate for the annual Hinkley C impingement as outlined in a paper provided by NRW in an email dated 5th July.

The scope of this report is the provision of an uncertainty estimate for all fish species recorded in the 2013 to 2022 surveys carried out as part of the Pembroke Environmental Monitoring Programme. The annual estimate is obtained in the same way as is done in the reporting, by summing monthly averages. The bootstrap confidence interval is obtained from both geometric and arithmetic monthly averages. The range between the upper confidence interval and the annual estimate varies between species and years reflecting the variation within the data being sampled. In general, the upper (95%ile) confidence interval is 1.6 to 2.0 times the calculated annual impingement, although it is higher for some species in some years.

The measure of uncertainty calculated from the bootstrapping methodology allows for an assessment of the range within which the annual impingement lies. While this approach allows for the relative uncertainty (both as an upper and a lower confidence interval) in the annual impingement catches, it is important to note that, contrary to the use of uncertainty at Hinkley, the impingement estimates alone are not being used to examine trends in fish populations, nor to assess the effect of abstraction at the power station. Rather the impingement data for Pembroke is considered in the context of the full monitoring programme where populations in the Haven are also being monitored. The Hinkley survey data, in comparison, was being used to predict impingement for a future development under different abstraction conditions.

Fundamentally, the analyses undertaken to date have not shown any underlying trends of change that are of ecological significance (Jacobs 2023a). This highlights that irrespective of the uncertainty calculated within the impingement data, abstraction at Pembroke Power Station is not having a negative effect on local fish populations.

Contents

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 has applied 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 the application PAN-025790 for renewal of Pembroke Power Station's water abstraction license 22/61/6/0156 (the Abstraction Licence Renewal).

2. NRW request for additional information & approach adopted

In an email dated the 16th July 2024 NRW confirmed validation of the Abstraction Licence Renewal application (PAN-025790) and requested further information including:

"Provision of the uncertainty/variability in annual entrapment estimates to account for sampling resolution and scaling uncertainties – bootstrapping process to apply for all species"

In an email dated 28th August NRW expanded on the requirements as follows: "*Conducting 40x24hr impingement samples each year gives temporal coverage of ~11%. Extrapolating this to 100% temporal coverage for a year introduces uncertainty and potential variability that needs to be explored and understood to account for it in the assessment. Furthermore, any averaging of entrapment or flow data during the process to calculate annual entrapment figures also introduces uncertainty and potential variability*".

NRW also provided a reference by email on 5th July to the use of bootstrapping as a means to determine confidence in impingement estimates from surveys at the Hinkley B power station (CEFAS 2018) as an example of the analysis that should be performed to support Pembroke's Abstraction Licence Renewal.

In responding to NRW's request it is important to define the terminology used when discussing the impact of abstraction on aquatic organisms. The following terms are all used, these are all linked but also have their individual elements:

- **Entrapment**: the entry into the cooling water system of aquatic organisms caused by the ingress of water. The term can encompass both impingement and entrainment or may alternatively be used interchangeably to describe either aspect.

- **Impingement**: the passage of entrapped organisms on cooling water intake screens that are employed to prevent debris and fish from entering the cooling water heat exchanges. To be impinged, organisms must be large enough to be retained by the screen meshes.
- **Entrainment**: the passage of entrapped organisms that penetrate the cooling water screens and are returned back to the estuary via the pumps, heat exchangers and other components of the cooling water circuit.

The effect of abstraction on the Haven is continuously assessed in the Pembroke Environmental Monitoring Programme through the entrapment pressure report (which looks specifically at entrainment and impingement) and the fish report (which looks at patterns across the full fish data set) (for example, Jacobs (2023b)).

Consequently, it should be noted that there is not a single entrapment data set (covering the sum of impingement and entrainment figures) that is suitable for the estimation of uncertainty. As part of the ongoing Pembroke Environmental Monitoring Programme agreed with NRW impingement is quantified from forty 24 hour surveys throughout the year while entrainment is quantified from nine 24 hour surveys from April to August. Within the annual monitoring reports provided to NRW, one of the methods used to assess the combined effect of impingement and entrainment is by using the Equivalent Adult Value (EAV) as a common metric. This provides a means to calculate an equivalent adult value to the different juvenile life stages sampled by the impingement and entrainment surveys. For any given species the entrainment survey will target the juvenile life stages (including eggs) that are small enough to pass through the main screens at Pembroke whilst the impingement survey can be expected to target older, larger fish. The EAV accounts for the natural mortality that different life stages of fish experience. In early life stages this is often extremely high so fish typically spawn a large number of eggs to compensate. The EAV is used to contextualise the abundance of different life stages observed in the entrainment and impingement surveys in terms of the equivalent number of adults. Calculating the EAV requires the creation of species specific life tables (where sufficient data is available) and allows for the comparison of entrapment pressures caused separately by impingement and entrainment. As an example the application of the EAV[1] to the juvenile sprat abundance in the entrainment surveys reduces the extrapolated raw abundance by 47%, therefore reducing the perceived magnitude of ecological pressure being placed on the species. This reduction is also seen in other species with a reduction of > 99.9% for herring, whiting, sea bass and Gobiidae (the latter being the most common species found). Whilst entrainment data includes eggs, the assignment of these to a particular species is extremely difficult and time-consuming therefore this aspect is assessed in terms of total abundance within the Entrapment Pressure report (Jacobs 2023a). A complete analysis of entrapment pressure is made in the Entrapment Pressure Report (Jacobs 2023a) which looks at both impingement and entrainment separately as well as collectively to look at overall pressure.

The entrainment surveys agreed with NRW as part of the Pembroke Environmental Monitoring Programme are focussed on the months of peak abundance with at most two surveys per month undertaken between April and August.

The entrainment and impingement abundance data sets both show a strong time dependence. For time series data the bootstrap is often applied over a block of time[2] or a model is used to allow for the time dependence. As an example, the R language, used in

[1] Pembroke Abstraction Licence Renewal Supporting Information:
Life Tables Document no: JUKL/B2382602/LIC/R08

[2] Discussion: Bootstrap methods for dependent data: A review

this and the Hinkley uncertainty study, provides a timeseries bootstrap function[3] that can implement a block sampling method or a model based replicate. For the entrainment data the limited number of samples available in any given month limits the use of time blocking whilst the strong interannual variability also precludes identification of a model.

Therefore, in line with the framework applied at Hinkley (CEFAS 2018), the estimates of uncertainty presented in this report have focussed on impingement. The assessment covers the annual impingement totals from 2013 to 2022, inclusive. The start year of 2013 was selected as it covers the first full year of operation. The uncertainty estimates have been obtained by bootstrapping the impingement data for every species recorded in the surveys.

3. Overview of the intake surveys

The following section provides an overview of the impingement surveys carried out at Pembroke Power Station as part of the Pembroke Environmental Monitoring Programme; full details of the results and discussion are provided in the annual reporting to NRW.

Pembroke Power Station operates under an environmental permit numbered EPR/DP333TA which requires the station to undertake comprehensive ongoing monitoring to continually assess any potential operational 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 the Conservation of Habitats and Species Regulations 2017 and the protection of the environment as a whole.

The following sections provide an overview of the survey technique and results.

3.1. Impingement Surveys

The survey procedure is detailed in Jacobs (2023a) but essentially consists of forty 24 hour impingement surveys per year. The Pembroke Power Station drum screens have a two stage screen wash with an initial low pressure spray to move fish into a fish return system and a secondary higher pressure spray to remove weed or trash. Having collected the 24 hour impingement samples ecologists identify, count and weigh the fish and other organisms. The total impingement data used in this report is the combination of both the fish recovery and return and the trash paths.

The current operational process is to rotate all drum screens no matter the cooling water flow. The survey records the impingement from all four drum screens over the 24 hour sampling period.

There have been 90 species of fish found during the ten years examined in this study. Of these there are a group that are found in every survey year and others that are rarer. The total abundance, number of surveys (out of 400) and number of years within which the species were observed, are tabulated in order of decreasing abundance below.

---

[3] tsboot function - RDocumentation

Table 1 Species observed in impingement surveys 2013 to 2022: total number found, number of surveys with an observation and number of years with an observation.

Species	Total Number observed 2013 to 2022	Number of surveys with the species observed	Number of years with the species observed
Sprat	463919	221	10
Sand smelt	116685	336	10
Sand goby	60806	283	10
Clupeid indet.	12611	149	10
Herring	6792	168	10
Rock goby	5700	329	10
Common goby	5478	281	10
Poor cod	5297	204	10
Bass	3584	177	10
15-spined stickleback	1733	240	10
Painted goby	1530	164	10
Grey gurnard	1329	143	10
Greater pipefish	1082	241	10
Lesser-spotted dogfish	1044	219	10
Pilchard	1005	54	7
5-bearded rockling	817	161	10
Golden grey mullet	757	145	10
Black goby	725	149	10
Whiting	650	123	10
Pollack	643	154	10
Snake pipefish	643	172	10
Transparent goby	573	127	10
Bib	528	129	10
Flounder	422	119	9
Mullet indet.	383	88	10
3-spined stickleback	264	56	10
Tub gurnard	242	42	10
Corkwing wrasse	238	91	10
European eel	219	109	10
Long-spined sea scorpion	217	122	10
Nilsson's pipefish	172	63	10
Thin-lipped grey mullet	143	35	8
Plaice	124	76	10
Dragonet (common)	112	72	10
Butterfish	100	79	10
Dab	86	44	7
Cod	73	28	8
Gilthead sea bream	67	24	8
Striped red mullet	56	24	8
Scad/Horse Mackerel	54	30	9
Lesser sandeel	45	25	9
Ballan wrasse	44	30	9
Pogge	38	28	7
Worm pipefish	38	29	8

Species	Total Number observed 2013 to 2022	Number of surveys with the species observed	Number of years with the species observed
Tompot blenny	35	24	8
Raitt's sandeel	33	14	5
2-spotted goby	28	21	9
Gobiidae	28	22	10
Sea lamprey	25	19	7
Gadoid indet.	24	16	5
Garfish	23	14	5
Short-spined sea scorpion	22	21	7
John dory	21	19	8
Mackerel	21	12	5
Shanny	20	20	9
Thick-lipped grey mullet	20	12	6
Dover sole	19	16	6
Thornback ray	19	17	9
Pipefish indet.	17	10	6
Lesser weever	15	7	4
Montagu's sea snail	12	10	5
Lumpsucker	10	9	5
Goldsinny wrasse	9	9	6
Sea trout	9	9	6
Dragonet (indet.)	8	7	4
Dragonet (reticulated)	8	6	4
Brill	7	6	4
Lozano's goby	7	6	4
Sandeel indet.	7	6	4
Long-snouted seahorse	5	5	3
Solenette	5	5	3
Wrasse indet.	5	3	3
Gurnard	4	4	4
Tadpole fish	3	2	2
Baillon's wrasse	2	2	2
Conger eel	2	2	2
Grey triggerfish	2	2	2
Haddock	2	2	1
2-spotted clingfish	1	1	1
Corbin's sandeel	1	1	1
Greater sandeel	1	1	1
Ling	1	1	1
Montagu's blenny	1	1	1
Salmonid	1	1	1
Sea bream indet.	1	1	1
Short-snouted seahorse	1	1	1
Smooth sandeel	1	1	1
Spiny seahorse	1	1	1
Starry smooth hound	1	1	1
Trisopterus sp.	1	1	1

As might be expected the most frequently found species, in terms of number of years and individual surveys, also tend to be the most the abundant, however the abundance is highly variable between the species impinged. As an example, butterfish were found in all 10 years with a total of 100 fish being found in 79 surveys (or about 20% of the 400 surveys undertaken). The most abundant species was sprat which was also found in all the years. There were a total of 463919 individuals recorded across 221 (55%) of the surveys undertaken. The most commonly recorded, as in the species recorded in the most surveys, is sand smelt which was found in 336 or 84% of surveys, there were a total of 116685 sand smelt recorded.

In total there are 33 species that were found in each of the annual surveys undertaken between 2013 to 2022 inclusive with a further 7 species being found in 9 of the ten years. There were 33 species that were found in 5 or fewer of the years surveyed. Thirteen of the species were only found in a single survey year while there were 12 species for which a single example was found in the 400 individual surveys undertaken.

The total number of fish in the impingement surveys from 2013 to 2022 are plotted below:

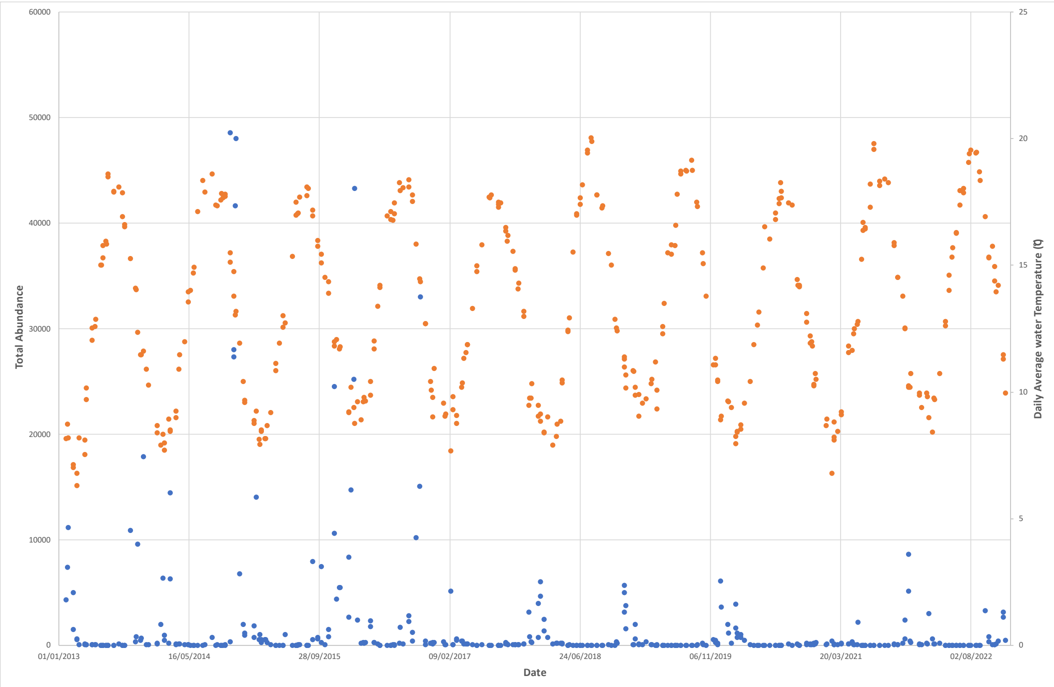

Figure 1 Total number of fish (blue) in each impingement survey 2013 to 2022 inclusive and daily average water temperature at intake (orange)

The number of fish recorded in the Pembroke 24 hour impingement surveys vary across any given year and between years. There are regular spikes in the number of fish impinged with these tending to be in the autumn and spring. A number of potential factors could influence the number of fish impinged such as the number of fish in the vicinity of the intake as well as the level of generation and hence rate at which cooling water is abstracted. Abstraction rate, ambient temperature and other possible influences on impingement are discussed further in Section 5.2 below.

The variation in total abundance by month is shown in Figure 2 below.

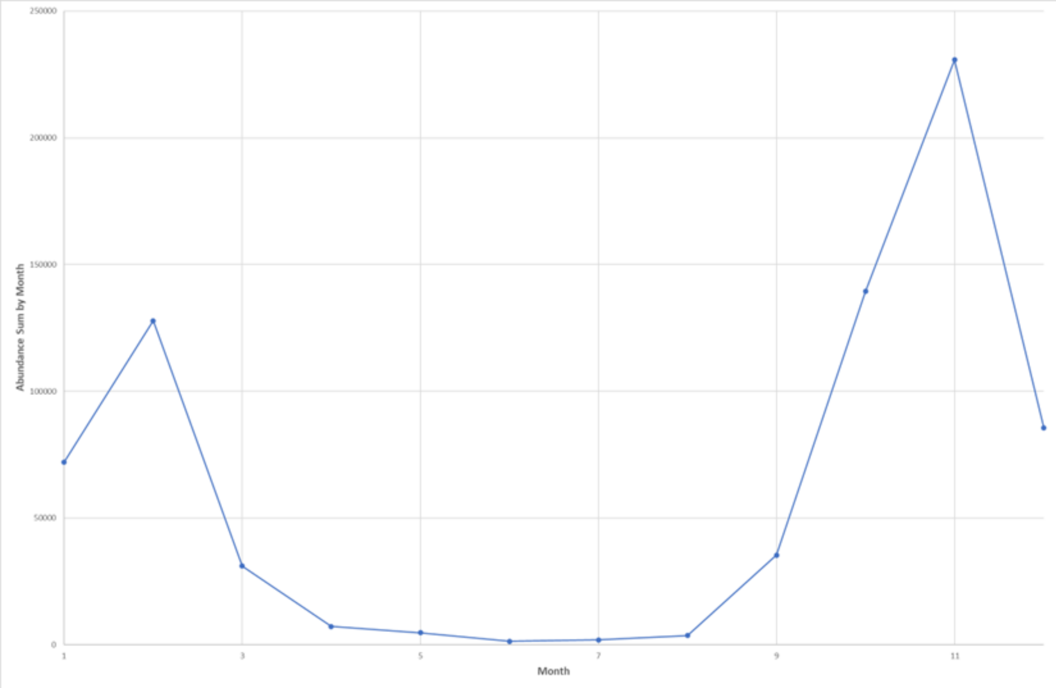

Figure 2 Total abundance by month 2013 to 2022 inclusive

Plotting the total abundance by month as in Figure 2 above shows peaks in the number of fish in the surveys in February and November. The relationship between the number of fish impinged and the time of the year is further illustrated in the following figures. The first (Figure 3) plots the total abundance by the day of the year. Both the magnitude and timing of the total abundance for each year varies but the pattern of low impingement during the summer and higher number in the spring and autumn are consistent between years.

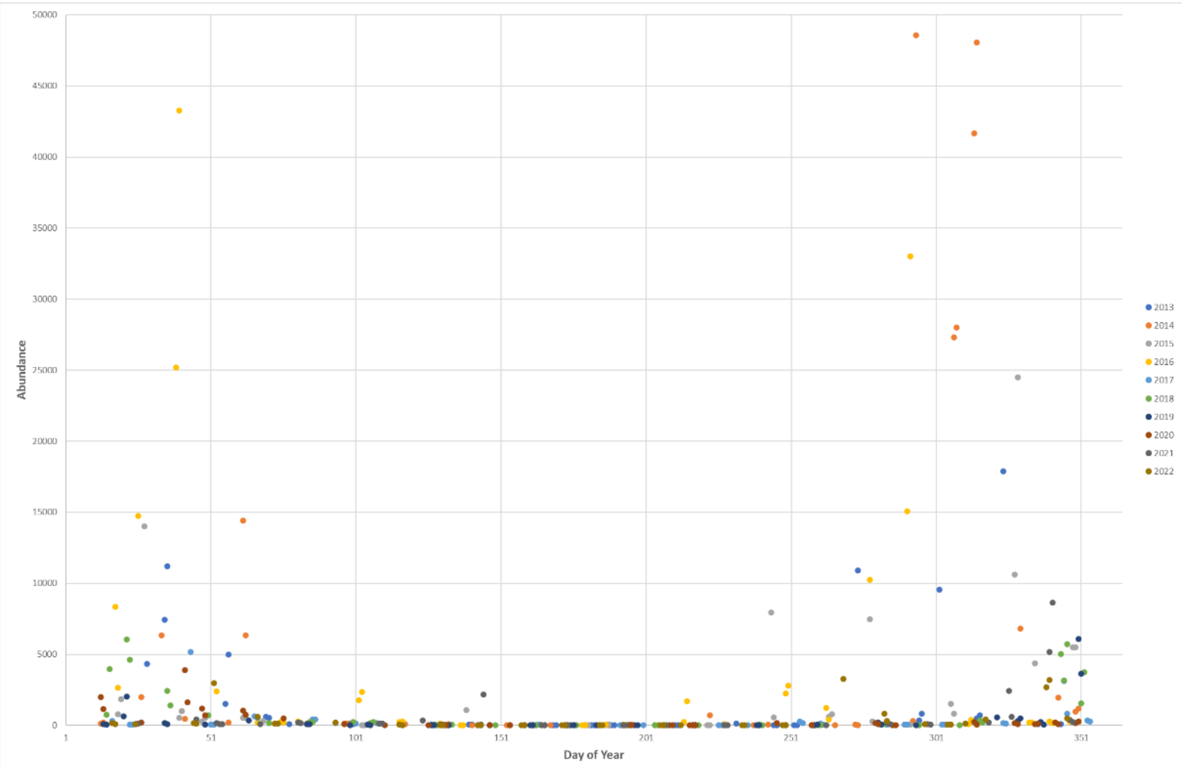

Figure 3 Abundance by Day of Year (2013 to 2022)

Sand Smelt are the most frequently observed species in the Pembroke surveys being found in all years and in 336 (84%) of the individual surveys. The number of sprat observed between 2013 and 2022 are plotted in Figure 4 below.

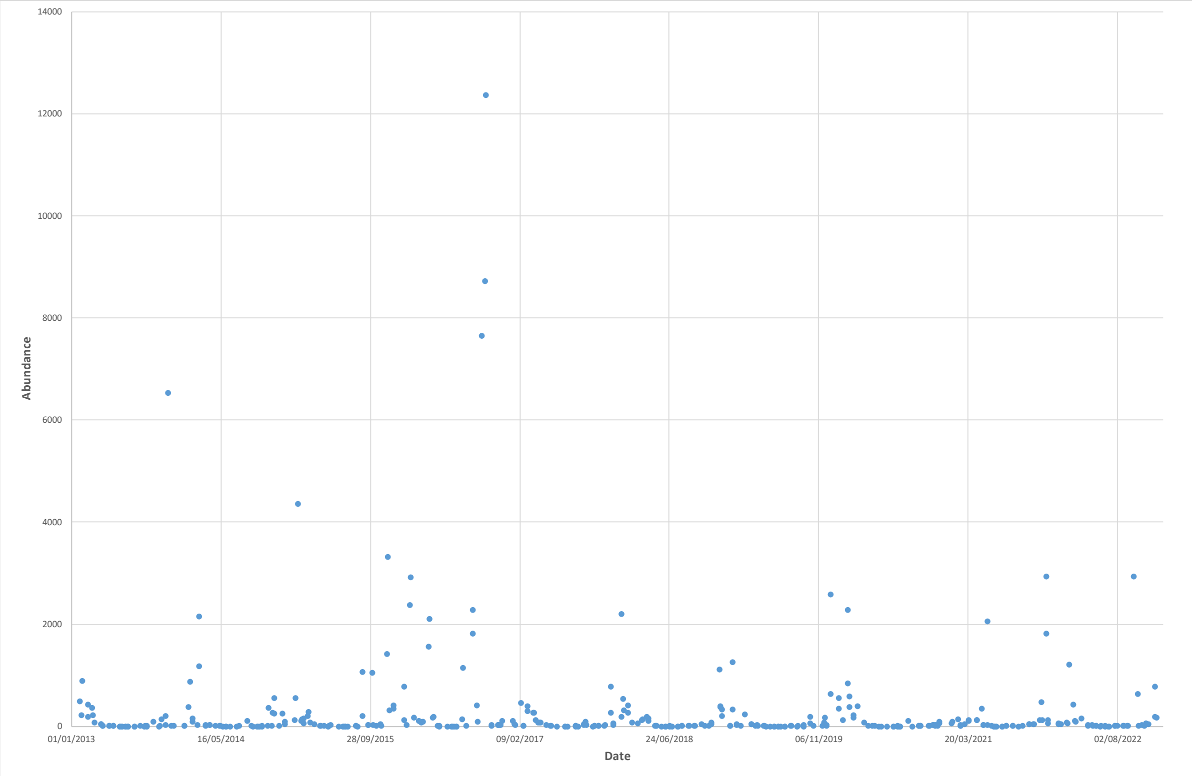

Figure 4 Abundance of sand smelt 2013 to 2022 inclusive

The numbers of sand smelt recorded in the surveys between 2013 and 2022 also highlight the variation over time of the impingement data. This time variation in the data will be a factor to be considered within the bootstrap. It will be necessary to undertake the bootstrap over a time period of less than a year in order to preserve the time variation, but if the averaging period for the bootstrap is too short the number of samples in each period will be limited. To address this the bootstrap has been calculated using one month as the averaging period to remain consistent with the calculation method used in the Pembroke Environmental Monitoring Programme annual reporting.

4. Overview of the Annual Estimate methodology

The methodology used to calculate annual impingement is outlined in the reporting (for example Jacobs 2023) and a worked example were provided as part of the renewal application on the 30th July 2024 (Impingement raw data and flows 2012-2022). The methodology is summarised below :

- For each species the individual survey results are used to calculate a monthly average abundance.
- This is scaled by the flow that was abstracted within the month and the monthly estimates then summed to obtain an estimate of the annual impingement.

The Pembroke Environmental Monitoring Programme annual reporting has used a geometric mean for the monthly abundance because it is considered to be a better measure of the observations. NRW has requested the survey data to be rerun as an arithmetic mean (Jacobs 2024) to allow comparison between the two approaches. Both methods are used within the present uncertainty analysis.

5. Sources of uncertainty in the annual estimates

The requirement identified by NRW is to estimate the uncertainty in annual estimates from sampling and scaling of the survey data.

The uncertainty in the annual estimate from the sampling resolution and scaling are discussed in more detail in the following sections.

5.1. Sampling Uncertainty

The number of each species observed in the surveys varies across and between years. There are species (see Table 1) that are recorded every year and in the majority of surveys. Of these the number in each month will also vary as is shown in the sand smelt abundance plotted as Figure 4. Analysis has shown that the main driver of the within year variation is the seawater temperature which reflects the seasonality. While patterns of abundance may repeat, the numbers vary between years and the 'signal' is not smooth. Other species are found only very rarely with, in the extreme, a single example being recorded in the 400 surveys undertaken between 2013 and 2022.

The surveys provide an approximation to the actual distribution of impingement abundance. The bootstrap method uses resampling of the sample data to draw inferences about the population (in a statistical sense).

5.2. Flow dependence of Impingement Surveys

As noted in Section 3.2, the Pembroke screens are fitted with a dual pressure wash system. The impingement surveys collect the total of the flow from the fish return system as well as any fish caught in the secondary line. The Pembroke drum screens are typically all in operation no matter the cooling water abstraction rate.

The power station operates within a dynamic electricity system and the generation and hence cooling water demand will vary with system needs. The variation in flow would influence the annual estimate if impingement were a function of flow rate. However, if this were the case the monthly average abundance obtained from samples undertaken during periods of low abstraction would be lower than that if the sampling was undertaken during period of higher abstraction which is not the case.

Figure 11 below, shows the cooling water flow rate at Pembroke for 2021 averaged over hourly, daily and monthly timescales.

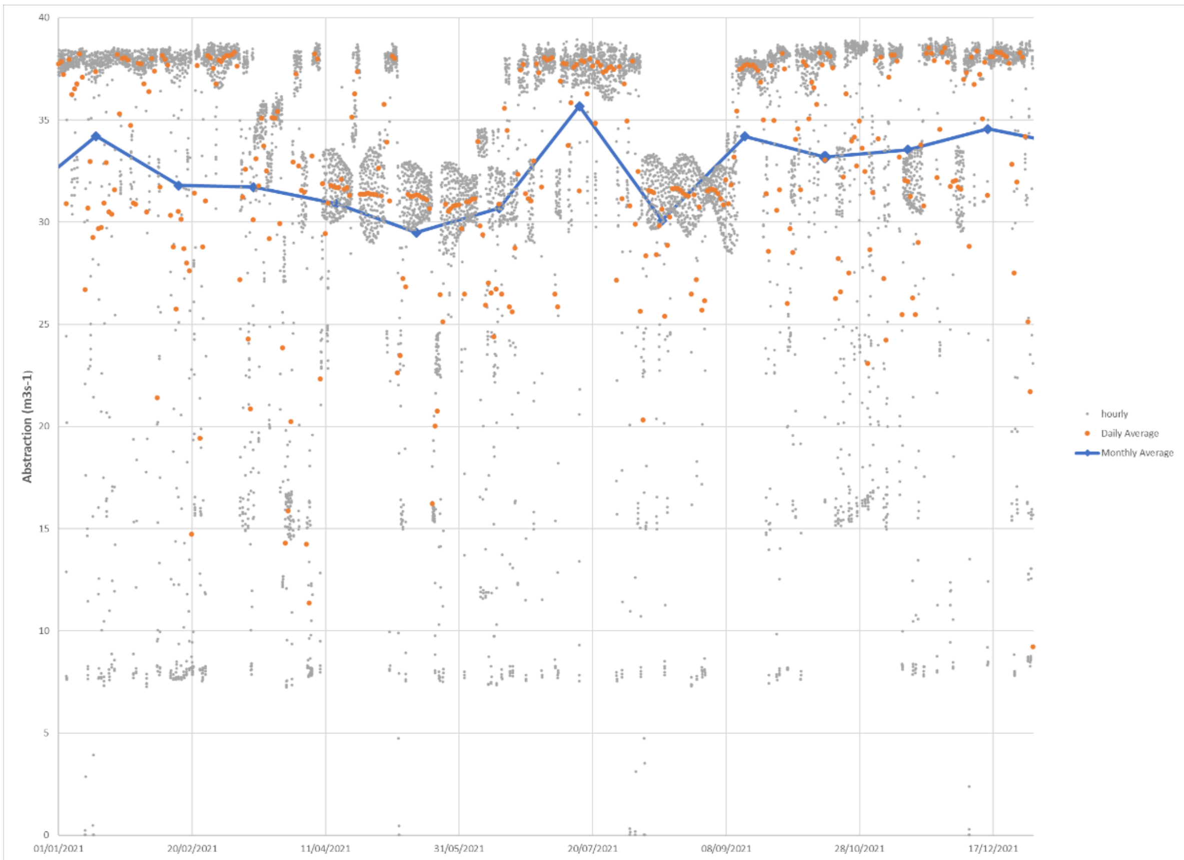

Figure 5 Cooling water flow in 2021, hourly (grey), daily average (orange) and monthly average (blue)

The variation in the hourly flow is seen as a cluster of grey around the orange daily averages. There are five generating units at Pembroke and the number of pumps in use will depend on the number of units generating. Each pump is nominally rated at $8m^3s^{-1}$ and the environmental permit controls both the maximum flow rate of the cooling water and the temperature rise across the station.

The 2018 entrapment report[4] includes an investigation of the factors that influence impingement rates. A Global BEST procedure was used to investigate which combination of abiotic factors best explained the variation in impingement abundance and biomass. The abiotic factors were:

- CW flow
- 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 during the survey

Of the factors examined, sea temperature had the strongest correlation to the abundance data. This was considered to reflect the link between seawater temperature and season; the impingement varies over each year with the highest abundance caught from late

[4] Appendix C: Pembroke Entrapment Monitoring: Quantification of Entrapment Pressure Jacobs July 2019

autumn to early spring (as seen in Figure 3). The other abiotic factors, including abstraction rate, did not have a statistically significant relationship to the impingement data.

6. Bootstrapping the Impingement sample data

NRW suggested the bootstrap method as a means to estimate the uncertainty in the annual entrapment estimates. In an email dated 5th July NRW provided a paper (CEFAS 2018) that applies a bootstrap to estimate uncertainty in annual impingement estimates at a power station intake.

In the context of the impingement survey data, the bootstrapping technique makes repeated samples from the survey data recalculating the annual estimate of impingement a large number of times. The resampling allows the method to build up an understanding of the variability in the annual impingement that could have been generated.

Bootstrapping has previously been used to estimate the uncertainty in annual impingement at the Hinkley B intake (CEFAS 2018), the work being used for the Hinkley Point C (HPC) DCO. As part of the impact assessment for the HPC power station EDF were able to draw on impingement surveys undertaken over several years at the current Hinkley Point B power station intake. There were two sampling programs. One was relatively low frequency but for multiple years and is known as the routine impingement monitoring program (RIMP). CEFAS noted that this has run for a 37-year period and consists of six hours of sampling from two of HPB's four drum screens every month. The RIMP impingement sampling is intended to identify longer terms trends in fish populations. The surveys are conducted during daylight, midway between springs and neaps, from high water on the ebb tide. In 2009/10 a higher resolution survey, similar to that undertaken at Pembroke since 2012, was carried out. This survey, named the comprehensive impingement monitoring program (CIMP), recorded the numbers and species of fish impinged by all four intake pumps over a full 24 hour period 40 times per year[5]. It was the higher resolution CIMP survey that was used within the CEFAS uncertainty study.

Whilst both the HPC CIMP and Pembroke surveys record all the impinged fish over a 24 hour period 40 times a year there are differences in the two sampling programs that influence bootstrapping. The CIMP program has exactly 10 surveys per quarter whilst the 40 Pembroke surveys are not uniformly distributed over the year. The survey dates within each month of the Pembroke program are randomly selected but the number of surveys per month are higher during periods with greater abundance. This allows a better resolution of peaks in abundance for the same number of surveys.

The CEFAS (2018) method to estimate the uncertainty from the sampling was as follows: *"The CIMP measurements of fish impingement at HPB were resampled with replacement within each quarter of the year to match the data collection procedure (10 visits per quarter). Then, for each of 10,000 bootstrap iterations, the sum of the 40 sampled values was calculated. 95% confidence intervals were derived from the resulting bootstrap distribution using the bias-corrected and accelerated (BCa) method for the confidence intervals (Efron, 1987; this method is a refinement of directly taking the percentiles). Next, the sum from the 40 samples and confidence limits were multiplied by 365.25/40 to give an annual estimate of HPB intake numbers. To estimate HPC intake numbers, the HPB result was multiplied by 131.86/33.7, to scale to the pumping capacities of the new and old stations. (Scaling the bootstrap intervals is valid as the method used is "transformation*

[5] This was followed with a second in 2021/22 – CEFAS (2022)

respecting" (Hall, 1992, page 137)). Bootstrapping was carried out in the software R v3.4.3 (R Core Team, 2017) using package 'boot' (Canty and Ripley, 2017)".

The HPC uncertainty estimate makes use of the uniform distribution of samples across the year and also implicitly assumes no influence of flow on the impingement rate at the Hinkley Point B intake. The final scaling is to allow for the difference between the abstraction rates of the surveyed site and the Hinkley Point C station. The intention of the EDF study was to derive an estimate of the forecasted impingement at a different location, for a different intake design and for a different operating regime (abstraction volume) than that at which the survey was undertaken. This is a different purpose than the Pembroke surveys which are instead measuring the impingement at an operational site and are used for an assessment of change alongside the full marine monitoring program in the Haven.

The bootstrap technique can be applied to a time series but, due to the presence of serial correlation, it is necessary to partition the data into temporal subsets that adequately reflects how the abundance data varies over time. The Pembroke surveys are undertaken on a monthly basis and the reporting uses monthly averages scaled by cooling water flow to sum to an annual estimate. To maintain consistency with the reporting the bootstrap has been applied to the monthly data.

Whilst the data does not show a strong relationship between the impingement and cooling water flow rate the data has been scaled using the flow to be consistent with the approach used in the annual reporting.

The process used in this report is as follows:

- For each year of the survey and each species with non-zero catch:
    - Scale the individual counts to account for flow variation within month
    - Bootstrap each month (R boot function with 10,000 samples as EDF/CEFAS) and obtain a monthly average
    - Calculate the annual estimate from the bootstrapped monthly averages
    - Calculate the confidence interval using the BCa method as CEFAS

The bootstrap method has been applied using both the geometric and arithmetic means of the survey data. The geometric mean uses the same approach as the annual reporting to handle zero counts.

6.1. Bootstrap Results

The bootstrap was applied to the surveys (2013 to 2022 inclusive) with the monthly average calculated as both a geometric and arithmetic mean. The results are tabulated below (Tables 2 to 11) including the ratio of the upper (95%ile) confidence interval (UCI) to the estimated annual impingement value (EAI):

Table 2 Bootstrap of 2013 impingement data: geometric & arithmetic mean

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Total Abundance	**427491**	**191552.7**	**968601**	**2.3**	**698637.9**	**410868.8**	**1245409.3**	**1.8**
Sprat	309305	133525.4	614453.5	2	444400.4	264777.7	686939.7	1.5
Sand smelt	42678.7	17897	234032.3	5.5	106015.9	29068.5	246158.8	2.3

	Geometric Mean				Arithmetic Mean			
Species	Estimated Annual Impingent	Lower Confidence Interval	Upper Confidence Interval	Ratio (UCI/EAI)	Annual	Lower Confidence Interval	Upper Confidence Interval	Ratio (UCI/EAI)
Sand goby	18491.6	4455.4	261230.8	14.1	99404.9	10722.6	273098.4	2.7
Herring	6338.5	2293.8	27981.4	4.4	15260.4	5384.3	35250.1	2.3
Common goby	905.2	333	1807.8	2	5173.5	939.4	13550.8	2.6
Poor cod	3698.8	2089.9	8946.3	2.4	5197.7	2811.3	9617.4	1.9
Rock goby	2768.7	1708.2	5108.8	1.8	3488.1	2284.6	5999.2	1.7
Painted goby	1902.7	930.2	3986.6	2.1	2525.7	1598.3	4250.1	1.7
15-spined stickleback	2003.5	1423.2	2717.5	1.4	2027.1	1620.2	2617.6	1.3
Flounder	1826.2	1446.4	2370.4	1.3	1744.2	1453	2287.1	1.3
Golden grey mullet	844.9	490.5	3101.2	3.7	1319.5	576.5	3242.3	2.5
Grey gurnard	1385.4	843.8	3230.1	2.3	1700.8	824.1	3170	1.9
Lesser-spotted dogfish	1426.4	1046.4	2178.2	1.5	1434.7	1085.9	2202.3	1.5
Greater pipefish	794	384.4	1068.8	1.3	872.6	676	1222.1	1.4
Snake pipefish	1009.8	635.3	1458.7	1.4	1058	798.5	1449.1	1.4
Black goby	1029	857.8	1305.1	1.3	885.5	799.3	1099.2	1.2
5-bearded rockling	552	282.5	1124.2	2	680.4	385.2	1249.5	1.8
Clupeid indet	1376.6	132.5	1583.9	1.2	1388.5	217	1495	1.1
Pollack	315.5	114.4	1051.9	3.3	514.6	190.5	1134.7	2.2
Whiting	367.7	118.3	646.9	1.8	583.7	383.2	987.9	1.7
Mullet indet.	496.3	279.8	780.2	1.6	512.1	366.1	741.5	1.4
Bib	380.1	177	625.4	1.6	469.1	298.9	808.6	1.7
European eel	352.3	114	694.3	2	435.7	287.2	673.4	1.5
Butterfish	288.4	142.6	412.1	1.4	291.9	216.8	424.1	1.5
Cod	363.1	208.5	649.4	1.8	356.6	215.5	596.8	1.7
Lesser sandeel	207.1	85	416.8	2	298.4	182.6	525.7	1.8
Raitt's sandeel	129.2	64.4	579.4	4.5	303	89.1	581.7	1.9
3-spined stickleback	255.1	76.9	396.8	1.6	277	109.7	374.8	1.4
Long-spined sea scorpion	322.7	175	522.6	1.6	319.5	260.8	438.7	1.4
Bass	311.8	183.1	455.4	1.5	280.6	222.1	353.7	1.3
Dab	195	80.7	353.6	1.8	226.7	150.9	359	1.6
Lesser weever	155.3	83.9	426.7	2.7	191	125.5	350.8	1.8
Transparent goby	102.4	69.2	206.8	2	158.2	107.3	229.9	1.5
Tub gurnard	117.2	57.4	254.4	2.2	194.9	116.1	306.2	1.6
Plaice	232.4	151.7	385.8	1.7	206.7	164.9	296.2	1.4

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Striped red mullet	117.5	61.8	248.5	2.1	163.4	92.6	243.2	1.5
Gadoid indet.	249.8	151.3	382.8	1.5	206.9	156.8	278.7	1.3
Scad	108.1	64.7	233.7	2.2	167.4	105.5	291.2	1.7
Pilchard	116.6	66.2	190.7	1.6	147.2	108.9	200.4	1.4
Gobiidae	153.4	78.7	383.3	2.5	177.9	112	306.9	1.7
Dragonet (common)	166.7	82.9	284.7	1.7	164.3	124.3	218.1	1.3
Sea lamprey	95.8	68	179.6	1.9	128.8	92.6	182.7	1.4
Short-spined sea scorpion	99.8	64.9	208.3	2.1	130.8	95.6	195	1.5
Corkwing wrasse	159.6	93.7	266.2	1.7	138.3	111.9	172.1	1.2
Nilsson's pipefish	84.1	70	198.9	2.4	107	77.8	186.1	1.7
Pogge	93.3	64.9	209.5	2.2	119.8	85.9	189.8	1.6
Garfish	85.8	69.7	217.5	2.5	116.5	76.7	200.6	1.7
Mackerel	89.2	68.9	192.7	2.2	115.6	83.7	183.1	1.6
John dory	88.3	69.3	149.2	1.7	99.9	82.7	137.4	1.4
Sandeel indet.	86.5	68	222.4	2.6	108.6	78	169.8	1.6
Ballan wrasse	89	66	195.1	2.2	102.2	75.4	140.6	1.4
2-spotted goby	81.1	70.5	171.4	2.1	93.6	70	140.2	1.5
Thornback ray	82.5	69.1	168.5	2	98.1	70	138.3	1.4
Lumpsucker	84.7	69.8	153	1.8	95.1	77.8	136.4	1.4
Sea trout	83.6	71.3	160.4	1.9	93.4	78	139.4	1.5
Solenette	82.7	72.8	147.6	1.8	90.2	77	127.4	1.4
Gilthead sea bream	82	69	140.9	1.7	88.5	73.9	109.5	1.2
Shanny	80.7	70.8	134.5	1.7	85.1	74.7	106.3	1.2
Goldsinny wrasse	80.8	70	138.7	1.7	85.6	75.1	108.4	1.3
Dragonet (reticulated)	80.7	71	134.5	1.7	85.1	74.7	106.3	1.2
Brill	81.9	70	138.3	1.7	88.1	72.5	108.2	1.2
Grey triggerfish	81.9	70	138.3	1.7	88.1	72.5	108.2	1.2
Salmonid	80	73.3	140.1	1.8	83.2	74	109	1.3
Trisopterus sp	80.8	70	138.7	1.7	85.6	75.1	108.4	1.3

Table 3 Bootstrap of 2014 impingement data: Geometric & arithmetic mean

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Total Abundance	**908655.6**	**160775.3**	**1478591**	**1.6**	**1740100**	**1004713**	**3101069**	**1.8**
Sprat	763025.8	34902.8	1257432	1.6	1539514	862208.1	2809433	1.8
Sand goby	18536.4	5903.4	36313.3	2	70422.3	33188.5	133982.6	1.9
Sand smelt	16433.7	4784.7	31539.9	1.9	56096.3	24848.3	102513.2	1.8
Common goby	9077.2	5420.7	15428	1.7	16831.9	9660.2	31032.6	1.8
Poor cod	5527.4	2793	11570.5	2.1	11598.9	5578	25932.2	2.2
Rock goby	6372.5	3955.3	9656.9	1.5	8184.3	5680.1	12549	1.5
Bass	3910.1	225.1	20552.1	5.3	8849.4	1094.4	21608.1	2.4
Herring	1973.3	845.3	4834.2	2.4	6442	2141.5	16154.5	2.5
Pilchard	149.7	61.2	418.1	2.8	3763.2	186.5	10951.9	2.9
Painted goby	1029	441.1	1426.8	1.4	2255.6	1260.3	4809.5	2.1
Whiting	785.3	359.1	1907.8	2.4	1831.7	726.2	4340	2.4
15-spined stickleback	1415.8	639.4	1879	1.3	1711.8	1191	2226.2	1.3
Black goby	1080.3	593.5	1949	1.8	1493.9	815.4	3112.8	2.1
Lesser-spotted dogfish	1150.5	715.9	1530.2	1.3	1297.4	939.3	1961	1.5
Grey gurnard	672.7	295.3	1087.9	1.6	973.3	559.2	1601.2	1.6
Pollack	453.5	209	747	1.6	958.7	412.1	2169.4	2.3
Snake pipefish	805.5	410.7	1045.1	1.3	903.5	612.4	1184.1	1.3
Bib	610.1	311.1	913.7	1.5	904.1	495.2	1830.1	2
Clupeid indet	201.3	67.6	655.8	3.3	841.9	242.5	1511.6	1.8
5-bearded rockling	766.8	455.1	1032.4	1.3	800.4	557.7	1146.5	1.4
Greater pipefish	757.1	435.4	950.4	1.3	850.9	641.7	1235	1.5
Flounder	721.2	434.3	955.1	1.3	719.4	549.7	884.7	1.2
Dab	414.9	142.1	579.5	1.4	511.6	359.6	774.5	1.5
Golden grey mullet	293.8	120.6	428.9	1.5	488.5	314.3	685	1.4
Transparent goby	209.4	66.2	345.3	1.6	498.7	246.3	1000.4	2
Mullet indet.	162.9	80.1	265.4	1.6	352.5	218.9	604.3	1.7
Cod	138.3	71.1	238	1.7	372.9	201.9	747.9	2
Nilsson's pipefish	150.2	67.4	290.7	1.9	402.4	210.4	773	1.9
European eel	263.9	92.5	345.7	1.3	374.8	266.5	506.1	1.4
Plaice	270.2	85.5	353.2	1.3	313.5	235.2	440.3	1.4

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Dragonet (common)	252.4	97.4	353.3	1.4	293.6	211.8	474.5	1.6
3-spined stickleback	173.2	93.4	303.4	1.8	211.9	144.1	337	1.6
Corkwing wrasse	113.6	71	213.7	1.9	223	139	385.6	1.7
Long-spined sea scorpion	190.4	85.2	294.1	1.5	223.5	159.1	337.1	1.5
Butterfish	140.5	76.9	206.6	1.5	190.2	141	251.8	1.3
Pogge	151	77.3	220.3	1.5	206.1	146	270.2	1.3
Striped red mullet	126.2	63.5	230.1	1.8	189.9	119.4	279.5	1.5
Mackerel	107.4	70.9	178.9	1.7	167.1	97.6	353	2.1
Tompot blenny	105.4	66	177.7	1.7	142	101.5	225.6	1.6
Tub gurnard	99.6	70.1	162.3	1.6	129.8	94	217.9	1.7
Lesser sandeel	92.9	71.6	175.9	1.9	127.2	90.2	219.1	1.7
Sea lamprey	108.9	67.3	176.5	1.6	125.9	88.8	157.4	1.3
Worm pipefish	96.8	68.9	169.6	1.8	128.9	94.9	189.9	1.5
2-spotted goby	99.3	69	159.5	1.6	119.4	91.4	174	1.5
Dover sole	95.2	70	165.4	1.7	122.2	92.4	175.4	1.4
Ballan wrasse	91.1	70.3	162.8	1.8	113.1	86.2	163.4	1.4
Gobiidae	90.5	68	183.4	2	119.9	85.8	191	1.6
Shanny	103.6	66	154.1	1.5	111	90.5	139.4	1.3
Goldsinny wrasse	101.5	68	158.4	1.6	113.4	86.4	138.2	1.2
Pipefish indet	85.1	69	166.8	2	103	78	166.1	1.6
Wrasse indet	83	69.3	202.7	2.4	109.2	70	171.5	1.6
Gilthead sea bream	81.1	71	175.9	2.2	94.3	73	143.3	1.5
Short-spined sea scorpion	86	70	157.9	1.8	99.4	78	142.3	1.4
Thornback ray	84.3	70.6	151	1.8	94.9	78	140.9	1.5
Montagu's sea snail	83.6	72	150.7	1.8	93.2	78	130.8	1.4
Scad	80.7	71	134.5	1.7	85.1	73	106.3	1.2
Raitt's sandeel	80.8	71	143.3	1.8	86.2	73.2	110.6	1.3
Gadoid indet.	80.7	71	134.5	1.7	85.1	73	106.3	1.2
John dory	80.3	72	138.5	1.7	84	74	108.2	1.3
Lesser weever	80.7	71	134.5	1.7	85.1	73	106.3	1.2
Lumpsucker	80.7	71	134.5	1.7	85.1	73	106.3	1.2

	Geometric Mean				Arithmetic Mean			
Species	Estimated Annual Impingent	Lower Confidence Interval	Upper Confidence Interval	Ratio (UCI/EAI)	Annual	Lower Confidence Interval	Upper Confidence Interval	Ratio (UCI/EAI)
Sea trout	80.8	71	143.3	1.8	86.2	73	110.6	1.3
Dragonet (indet)	82	71	141.8	1.7	88.6	73	109.9	1.2
Lozano's goby	80.7	71	134.5	1.7	85.1	73	106.3	1.2
Sandeel indet.	81.9	70.3	138	1.7	88	72	108	1.2
Baillon's wrasse	80.3	72	138.5	1.7	84	74	108.2	1.3
Conger eel	80.8	71	143.3	1.8	86.2	73	110.6	1.3
Montagu's blenny	80.8	71	138.4	1.7	85.6	73	108.2	1.3

Table 4 Bootstrap of 2015 impingement data: Geometric & arithmetic mean

	Geometric Mean				Arithmetic Mean			
Species	Estimated Annual Impingent	Lower Confidence Interval	Upper Confidence Interval	Ratio (UCI/EAI)	Annual	Lower Confidence Interval	Upper Confidence Interval	Ratio (UCI/EAI)
Total Abundance	**456545.9**	**192127.5**	**868791.6**	**1.9**	**823332.5**	**474960**	**1455248**	**1.8**
Sprat	220437	76372.7	438021.5	2	467479.7	251708	848444.7	1.8
Sand smelt	51130.9	21276.5	139271.3	2.7	131380.6	61921.2	263482.1	2
Sand goby	46307.5	11653.1	128756.1	2.8	116693.7	45845.4	230920.2	2
Clupeid indet	4433.7	452.6	15785.1	3.6	30365.8	13243.7	60471	2
Herring	4626	1832.9	8218.7	1.8	22238.8	6001.6	65824.1	3
Rock goby	8822.4	4550.2	16098.1	1.8	14143.3	8033.7	24739.2	1.7
Poor cod	5614.1	2017.5	8168	1.5	7585.2	4769.9	11161.6	1.5
Common goby	3217.5	1719.8	5097.3	1.6	4856.9	3020.5	7682.3	1.6
Bass	3398.9	1734.1	4956.2	1.5	4163.5	2640.6	5795.9	1.4
Grey gurnard	1881.1	483.5	4534.5	2.4	3777.2	1665.9	6773.9	1.8
Painted goby	1240.9	284.7	4417.8	3.6	3110.5	707.2	5595.5	1.8
15-spined stickleback	1644.1	915.8	2559.8	1.6	2155.4	1308.7	3298.1	1.5
Tub gurnard	677.2	85.1	2212.8	3.3	1485.1	540.5	2970.1	2
Lesser-spotted dogfish	1426	713	1921	1.3	1507.1	1074.6	2221.1	1.5
Pollack	738.5	250.7	1012.7	1.4	1490	673.2	3119.2	2.1
Pilchard	246.9	73.3	621.6	2.5	1443.8	317.3	3666.7	2.5
Mullet indet.	352.8	161.5	496.3	1.4	1119.8	366.7	2934.7	2.6
5-bearded rockling	1192.2	635.9	1614.3	1.4	1250	862.5	1612.8	1.3
Greater pipefish	768.5	319.3	1147.8	1.5	1188.8	701.1	1921.3	1.6
3-spined stickleback	548.3	88	1322.2	2.4	1221.9	470.1	2056.7	1.7
Black goby	427.9	146.4	597.6	1.4	939.3	479.6	1650.9	1.8
Transparent goby	201	61.7	405.8	2	896.3	240.8	2160.2	2.4
Snake pipefish	606.9	205.2	878.2	1.4	748	476.2	1270.7	1.7
Golden grey mullet	137	62.9	283	2.1	624.4	122	1245.2	2

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Bib	324.1	84.7	676.9	2.1	588.6	315.2	1021.6	1.7
Flounder	253.9	94.5	368.1	1.4	421.2	251	698.2	1.7
Whiting	177.9	50.2	325.9	1.8	353.4	206.7	547.2	1.5
Plaice	160.2	57.8	274.7	1.7	306.1	182.7	470.6	1.5
Corkwing wrasse	218.3	92.9	353.5	1.6	279.8	169.4	488	1.7
Long-spined sea scorpion	223.3	77.5	316	1.4	265.6	188.9	371.4	1.4
European eel	171.9	72.9	231.5	1.3	249.9	179.8	354.6	1.4
Dragonet (common)	197.7	80.1	281.4	1.4	224.3	156.4	360	1.6
Pogge	114.7	70.4	210.7	1.8	170	112.7	260.7	1.5
Dover sole	99.7	70.1	207.4	2.1	161.8	108.3	271.3	1.7
Nilsson's pipefish	93.6	70.3	244.3	2.6	157.5	93.8	286.5	1.8
Butterfish	153.5	90	278.3	1.8	159.6	114.1	250.8	1.6
Dab	103.1	69.7	183	1.8	144	101.8	199.4	1.4
Scad	106.3	64.4	189.2	1.8	150.4	102.5	231	1.5
Thin lipped grey mullet	161.6	134.2	268.1	1.7	141.3	109.6	204.6	1.4
2-spotted goby	107	69	185.6	1.7	138.7	98.7	196.4	1.4
Garfish	112.9	71	175.5	1.6	132.7	101.8	180.2	1.4
Thornback ray	108.7	63.2	196.6	1.8	146.2	101.4	213.2	1.5
Tompot blenny	88.1	68.9	200.1	2.3	119	84.1	205.9	1.7
Raitt's sandeel	153.9	137.1	243.3	1.6	129.2	109.9	176.6	1.4
Cod	99	64	174.5	1.8	117.2	78	158.2	1.3
Short-spined sea scorpion	89.4	68.8	183	2	117.3	84.1	183.2	1.6
Montagu's sea snail	85.3	68.6	203.2	2.4	111.5	78	194.4	1.7
Lumpsucker	87.8	69.8	173.8	2	110.9	83.1	175.5	1.6
Ballan wrasse	88.7	70.3	160.1	1.8	106.6	82.3	156.1	1.5
Gilthead sea bream	84.8	68.8	149	1.8	96.2	78	140.2	1.5
Lesser sandeel	85.5	67	134.9	1.6	92.2	73.1	106.4	1.2
Gobiidae	86.5	69.5	179.6	2.1	104.1	78	156.4	1.5
Shanny	86.5	69	179.6	2.1	104.2	78	156.6	1.5
Sea trout	86	70	156.4	1.8	99.2	78	141.6	1.4
Haddock	84.8	69	149	1.8	96.2	78	140.2	1.5
Worm pipefish	82	69	141.2	1.7	88.5	73	109.6	1.2
Sea lamprey	82	70	141.5	1.7	88.6	73	109.7	1.2
John dory	82	68	141.2	1.7	88.5	72	109.6	1.2
Mackerel	80.8	70.5	139.2	1.7	85.6	73.6	108.6	1.3
Goldsinny wrasse	80.9	70.9	147.6	1.8	86.7	74	112.8	1.3
Long-snouted seahorse	80.8	71	138.4	1.7	85.6	73.6	108.2	1.3
Solenette	82	70	141.7	1.7	88.6	73.4	109.9	1.2
Grey triggerfish	80.8	70.8	139.2	1.7	85.6	73	108.6	1.3
2-spotted clingfish	82	70	141.6	1.7	88.6	73	109.8	1.2

Table 5 Bootstrap of 2016 impingement data: Geometric & arithmetic mean

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Total Abundance	**1256224**	**465886.5**	**2140823**	**1.7**	**1706790**	**928496.3**	**2643395**	**1.5**
Sprat	638515.8	196507	1333924	2.1	960929.6	412802.1	1646900	1.7
Sand smelt	372122	72295.7	487561.5	1.3	446842.8	351154.4	588001.2	1.3
Sand goby	53595	5368	171092.3	3.2	142672.6	27637.4	233553.3	1.6
Clupeid indet	21822.2	1056.5	143613.4	6.6	74834	5714.4	150386.4	2
Common goby	11638.3	2836.5	17806.7	1.5	13584.2	8878.5	19845	1.5
Poor cod	9590.2	4327.6	15433.5	1.6	12570.6	6901.2	18633.2	1.5
Rock goby	8310.4	2354.2	20019.4	2.4	11630.1	4250.5	20993.5	1.8
15-spined stickleback	5173.3	3392.8	10627.3	2.1	6410.2	3861	11101	1.7
Bass	1489.5	423.2	2595.4	1.7	5168.7	2763.6	9046	1.8
Herring	2481.5	683.2	9367.9	3.8	4763.8	1237.9	9903.1	2.1
Grey gurnard	2441.7	855.1	6431.7	2.6	4294.9	1952.1	8460.3	2
Golden grey mullet	1789.3	834.5	2888.2	1.6	2668.8	1600	4346.4	1.6
Black goby	1591.1	578	2772	1.7	2277.1	1250.1	3795.4	1.7
Greater pipefish	1390.1	503.5	2050.7	1.5	2201.3	1354.6	3398.1	1.5
5-bearded rockling	1850.7	886.8	2473.5	1.3	2026.7	1583	2801.6	1.4
Snake pipefish	1656.3	916.8	1858.8	1.1	1627.5	1397.7	1841.8	1.1
Lesser-spotted dogfish	1421.3	887.6	1892.4	1.3	1580.2	1170.5	2247.5	1.4
Whiting	654.6	217.6	1365.4	2.1	1324.4	642.4	2604.8	2
Pilchard	378.8	108.1	715.5	1.9	1264.1	385.7	3012.5	2.4
Pollack	639.2	156	1350.1	2.1	1267.8	593.5	2335.4	1.8
Painted goby	340.5	122.8	461.1	1.4	1036.3	347.8	2393.1	2.3
Thin lipped grey mullet	261.5	89.8	519.1	2	926.1	359.3	1870.1	2
European eel	680	312.3	1133.2	1.7	847.6	513.5	1410.4	1.7
Flounder	734.7	507.6	1026.7	1.4	734.5	545.7	1071.4	1.5
Bib	204.8	69.3	529.7	2.6	791.9	371.6	1500.2	1.9
3-spined stickleback	577.1	153.2	1368.5	2.4	768.7	197.8	1360.4	1.8
Long-spined sea scorpion	790.3	555.6	935.9	1.2	691.4	536.5	840.2	1.2
Transparent goby	215.7	77.4	357.4	1.7	600.3	269.5	1074.7	1.8
Plaice	355.3	105.5	440.2	1.2	351.5	273.5	465.4	1.3
Corkwing wrasse	247.4	83.6	363.4	1.5	316.8	202.6	433.6	1.4
Mullet indet.	268.1	96.7	352.4	1.3	297.8	225.2	403.1	1.4
Tub gurnard	271.1	84	384.9	1.4	281.9	135.2	363.9	1.3
Striped red mullet	263.7	75.8	361.6	1.4	264.5	189.9	349.7	1.3
Scad	147	66.6	268.3	1.8	244.9	154.7	392.2	1.6
Nilsson's pipefish	100.1	66	227.9	2.3	221.6	107.9	437.6	2
Tompot blenny	110.2	67.7	205.5	1.9	188.8	111.6	340.2	1.8
Dragonet (common)	124.4	70.5	206	1.7	171.9	117.6	230.1	1.3

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Butterfish	119.4	70.8	195.9	1.6	170.8	121.6	242.3	1.4
Garfish	87.4	69	370.3	4.2	170.6	78	357.4	2.1
Thick lipped grey mullet	93.3	69.1	225.3	2.4	141.2	85.8	244.9	1.7
Pipefish indet	87.1	70	337.2	3.9	160	78	325.6	2
Cod	95.7	70.5	170	1.8	131.4	96.9	203.1	1.5
Gilthead sea bream	115.2	67	190	1.6	139	100.3	186.5	1.3
Short-spined sea scorpion	111.4	68	177.2	1.6	131.3	101	178.1	1.4
Ballan wrasse	91.9	70.5	172.3	1.9	121.9	89.8	187.8	1.5
Lesser sandeel	87.8	71.8	174.6	2	111.1	84.4	176.9	1.6
John dory	99.9	65.3	175.7	1.8	119.1	79.8	163	1.4
Pogge	85.4	70	178.1	2.1	106.9	78	172.7	1.6
Worm pipefish	85.4	68.4	177	2.1	106.7	78	172	1.6
Gobiidae	85.2	69.1	170.1	2	104.7	78	173.1	1.7
Sea lamprey	88.7	70.8	146.4	1.7	101.2	79.7	131.7	1.3
Montagu's sea snail	97.8	67.8	152.9	1.6	108.9	82.6	139.1	1.3
Thornback ray	84.8	70	149	1.8	96	78	139.6	1.5
Lumpsucker	84.8	70	149	1.8	96.1	78	139.7	1.5
Sea trout	85.9	66.2	140.9	1.6	93.7	73.9	109.4	1.2
Dragonet (reticulated)	84.8	70.3	149.1	1.8	96.4	78	141.1	1.5
Brill	84.8	70	149	1.8	96.1	78	139.8	1.5
Solenette	93.2	65	137	1.5	97.7	73	107.5	1.1
Dab	80.8	71	138.2	1.7	85.5	73	108.1	1.3
Mackerel	82	70	141.2	1.7	88.5	73.9	109.6	1.2
Shanny	82	70	140.3	1.7	88.4	73	109.1	1.2
Dover sole	82	70	141.2	1.7	88.5	72.3	109.6	1.2
Lesser weever	81.9	69.9	137	1.7	87.8	74.8	107.5	1.2
Sandeel indet.	82	70	141.2	1.7	88.5	73.9	109.6	1.2

Table 6 Bootstrap of 2017 impingement data: geometric & arithmetic mean

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Total Abundance	**65017.7**	**41296.3**	**200032.2**	**3.1**	**122754.2**	**54479.5**	**255411.6**	**2.1**
Sprat	8832.5	2630.3	49084.1	5.6	55743.1	8918.7	147148.7	2.6
Sand smelt	21950	15554.2	37235.7	1.7	30041.4	19698.3	49515.4	1.6
Sand goby	4668.7	2131.4	11589.3	2.5	10726.5	4405.7	26899.5	2.5
Bass	3981.3	2817.4	5073.4	1.3	4116	3057.9	5118	1.2
Rock goby	2920.6	1831.6	4591.9	1.6	3613.2	2458.3	5983.8	1.7
Clupeid indet	1076.6	210.5	2145.8	2	2669.9	1415.6	5383	2
Herring	575.9	278.3	1343.9	2.3	2561.3	537.4	6555.9	2.6
Poor cod	1370	880.2	3672.5	2.7	2002.9	996.2	3942.4	2
Common goby	871.7	451.8	1487.7	1.7	1605.7	841.3	3254.2	2
15-spined stickleback	1091.8	611.2	1436.7	1.3	1210	847.8	1630.9	1.3
5-bearded rockling	1215	715.3	1752	1.4	1220.2	918.3	1697.5	1.4
Lesser-spotted dogfish	965.6	569.2	1294.3	1.3	1065.2	810.8	1498.3	1.4
Greater pipefish	775	459.8	1168.2	1.5	881.7	614.4	1386.8	1.6
Whiting	268.2	115.2	410.4	1.5	804.8	380.7	1621.1	2
Grey gurnard	537.6	327.5	714.4	1.3	598	463.6	828.7	1.4
Transparent goby	681.4	290	1122.3	1.6	779.4	514.1	1105.8	1.4
Pilchard	225.5	97.9	575.1	2.6	457.7	183.6	985.8	2.2
Bib	265.2	71.7	483.1	1.8	390.3	233.1	615.9	1.6
Painted goby	136.9	75.3	312.3	2.3	363.6	165.9	744.5	2
Gilthead sea bream	127.7	68.7	262.8	2.1	350.2	132.1	775.1	2.2
Pollack	384.4	232.8	551.1	1.4	365.6	286.5	540.2	1.5
Snake pipefish	221	88.9	289.7	1.3	329.6	243.5	425.8	1.3
Golden grey mullet	298.8	129.2	411.2	1.4	324.2	241	464.8	1.4
European eel	142.1	74.8	227.4	1.6	280.2	172.7	536	1.9
Black goby	178.9	81.7	246.3	1.4	250.1	183.8	360.4	1.4
Long-spined sea scorpion	243.4	96.5	314.7	1.3	264.4	208.9	349.9	1.3
Nilsson's pipefish	153.9	71	242.3	1.6	258.4	172	422.1	1.6
Flounder	237.3	131.9	355	1.5	256.5	188.3	386.1	1.5
Corkwing wrasse	149.2	73	218.1	1.5	238	163	383.9	1.6
Mullet indet.	219.9	130.6	471.7	2.1	240.4	129.4	444.7	1.9
Ballan wrasse	133.9	62.5	231	1.7	206.8	140	298.9	1.4
Thin lipped grey mullet	98.9	70.4	333.5	3.4	173.9	88.7	337.6	1.9
Tub gurnard	97.5	67	233.7	2.4	148.7	88.5	258.7	1.7
Dragonet (common)	120	74.5	189.4	1.6	150.6	114.6	214.1	1.4
3-spined stickleback	108.1	61	268.9	2.5	158.7	89.1	276.9	1.7
2-spotted goby	106.8	67.1	222.2	2.1	148.4	96.8	237.5	1.6
Butterfish	99.8	70.2	178.4	1.8	131.1	98	186.3	1.4
Plaice	91.2	70.9	180.1	2	115.1	88.1	177.4	1.5

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Sea lamprey	93.7	68.8	156.3	1.7	108.9	85.8	139.7	1.3
John dory	90.2	71.7	169.9	1.9	106.3	84.5	163.1	1.5
Lesser sandeel	88.6	70.8	163.7	1.8	105.7	83.3	158.4	1.5
Short-spined sea scorpion	86	72.6	154.3	1.8	98.1	82.1	134.5	1.4
Mackerel	89.7	69.7	155.3	1.7	103	82.4	137.4	1.3
Brill	83.9	72	180.1	2.1	101.3	78	161	1.6
Long-snouted seahorse	85.9	72.8	162.1	1.9	99.7	81.6	147.7	1.5
Striped red mullet	83.1	72.9	156.7	1.9	92.1	77.8	130.4	1.4
Raitt's sandeel	88.8	69.8	154.7	1.7	96.3	79.8	124.9	1.3
Gobiidae	87.1	71.7	141.3	1.6	92.1	79.8	125.1	1.4
Garfish	84.8	71	155.9	1.8	96	78	139.5	1.5
Shanny	84.8	70.6	156.5	1.8	96.1	78	139.8	1.5
Thick lipped grey mullet	82.4	71	162.4	2	96.8	72	134.3	1.4
Pipefish indet	87.7	70.3	147.7	1.7	93.7	80	125.1	1.3
Cod	81.8	71	134.3	1.6	87.4	72	106.1	1.2
Scad	82	71	140.5	1.7	88.4	73	109.3	1.2
Tompot blenny	80.8	72	140.9	1.7	85.9	72	109.4	1.3
Dover sole	80.8	72	138.5	1.7	85.6	73.1	108.3	1.3
Thornback ray	80.8	72	138.5	1.7	85.6	72	108.3	1.3
Sea trout	81.8	71	134.3	1.6	87.4	72	106.1	1.2
Dragonet (indet)	81.8	71	134.3	1.6	87.4	73	106.1	1.2
Lozano's goby	82	71	140.5	1.7	88.4	72	109.3	1.2
Gurnard	81.8	72	134.3	1.6	87.4	72.1	106.1	1.2
Baillon's wrasse	80.8	72	140.9	1.7	85.9	72	109.4	1.3
Conger eel	80.8	72	140.9	1.7	85.9	72	109.4	1.3
Corbin's sandeel	80.8	72	138.5	1.7	85.6	72	108.3	1.3

Table 7 Bootstrap of 2018 impingement data: geometric & arithmetic mean

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Total Abundance	**264417.3**	**139867.6**	**352050.3**	**1.3**	**309319.5**	**196928.3**	**389016.3**	**1.3**
Sprat	151260.7	87675	250540.5	1.7	193161.8	115718	279283.3	1.4
Sand smelt	44320.2	29616.3	90896	2.1	58532.6	37761.7	109689.3	1.9
Sand goby	16440.8	4041.6	40714.4	2.5	28491.2	8895.3	50180.5	1.8
Poor cod	3849.4	1295.6	6219.9	1.6	5863.4	3507	9079	1.5
Bass	4331.3	2735.9	6998.8	1.6	4967.9	3192	7425.3	1.5
Herring	995.4	454.3	2472	2.5	2712.3	1071.7	5423.5	2
Common goby	1863.7	874.6	2520.4	1.4	2703.1	1917.8	4738.4	1.8
Clupeid indet	746.1	84.8	3740	5	2938.4	639.9	6054.2	2.1
Rock goby	1551.8	866.4	2046.2	1.3	2102.1	1546.7	3232.1	1.5
Lesser-spotted dogfish	815.1	249.1	1057.1	1.3	1116.6	791.1	1666.8	1.5
Bib	707	454.7	986.3	1.4	739.8	528.4	1112.6	1.5
Pilchard	295.1	75	427.7	1.4	704.2	345.9	1795.4	2.5
5-bearded rockling	680.9	297.7	916.7	1.3	677.7	456.2	929.2	1.4
15-spined stickleback	751.2	449.2	928.7	1.2	749.3	585.3	958.4	1.3
Greater pipefish	430	124.1	560.8	1.3	610.9	431.4	1008.8	1.7
Golden grey mullet	517.4	232	767.5	1.5	604	414.2	958.1	1.6
Grey gurnard	414.6	269	647.3	1.6	450.3	266.8	752.4	1.7
Whiting	462.7	292.5	600.5	1.3	460.2	344.9	639.9	1.4
Transparent goby	415.5	180.8	572	1.4	432.4	267.2	588.6	1.4
Pollack	295.3	106.1	384.1	1.3	359.6	265.8	509.6	1.4
Black goby	283.8	82.5	376.3	1.3	341.3	249.5	437	1.3
Nilsson's pipefish	209.4	73.4	298	1.4	298.6	200.4	528.6	1.8
Flounder	354.2	247.3	474.2	1.3	302.2	236.8	421.5	1.4
Gilthead sea bream	126.2	67.9	237.8	1.9	263.2	141.9	588.5	2.2
Corkwing wrasse	196.7	95.4	288.1	1.5	220.8	162.9	301	1.4
Long-spined sea scorpion	197.6	87.6	294.9	1.5	218.1	159.7	293.2	1.3
Tub gurnard	115.1	72.5	190.8	1.7	173.4	113.4	362.8	2.1
Snake pipefish	113.6	69.8	190.2	1.7	173.2	122.6	261.9	1.5
Mullet indet.	106.6	68.2	194.6	1.8	157	109.8	245.9	1.6
3-spined stickleback	107.4	69.4	189.7	1.8	162.2	112	245	1.5
Plaice	113.1	69.1	193.7	1.7	152.2	108.1	205.9	1.4
European eel	104.6	71.1	179.2	1.7	142.6	106.4	201.8	1.4
Dab	118.1	68.8	185.2	1.6	137	105.9	203.6	1.5
Thin lipped grey mullet	105.6	67.1	234	2.2	146	92.2	238.4	1.6
Dragonet (common)	110.4	65.3	186.3	1.7	132.7	78	169.8	1.3
Butterfish	95.5	70	183.6	1.9	130.2	94.2	204.1	1.6
Scad	104.3	68.1	177.6	1.7	139	100	209.1	1.5
Ballan wrasse	88.1	69.8	208.9	2.4	122.8	80.9	206.4	1.7

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
John dory	101.1	62.7	173.7	1.7	121.5	85.4	163.2	1.3
Thick lipped grey mullet	94.6	69	177.7	1.9	121.6	90.4	178.4	1.5
Dragonet (indet)	99.3	63.6	156.6	1.6	117.8	88.9	165.7	1.4
Dragonet (reticulated)	84.2	69	175.1	2.1	103.9	78	142.7	1.4
Lesser sandeel	82.8	68	190.8	2.3	106.2	69	162.6	1.5
Sea lamprey	86.5	68	183.9	2.1	109.6	78	172.8	1.6
Painted goby	80.5	70.1	175.1	2.2	90.9	73.4	142.7	1.6
Cod	83.1	71	149.6	1.8	92.4	78	131.6	1.4
Striped red mullet	84.8	69	151.9	1.8	96	78	139.8	1.5
Worm pipefish	84.3	70.3	150.4	1.8	95.2	78	141.9	1.5
2-spotted goby	85.9	67.2	140.5	1.6	93.6	74.4	109.3	1.2
Thornback ray	84.8	69	151.5	1.8	96	78	139.8	1.5
Sandeel indet.	84.8	69	149.5	1.8	96	78	139.8	1.5
Tompot blenny	80.3	70.8	142.7	1.8	84.5	73.4	110.4	1.3
Gobiidae	80.8	70	141.8	1.8	86	73.3	109.9	1.3
Gadoid indet.	82	69	140.9	1.7	88.5	71	109.5	1.2
Pipefish indet	81.9	68	139.1	1.7	88.2	70	108.6	1.2
Goldsinny wrasse	80.8	70	140.5	1.7	85.8	73.2	109.3	1.3
Brill	80.3	71	142.7	1.8	84.5	73.4	110.4	1.3
Lozano's goby	80.3	70.6	142.7	1.8	84.5	73.4	110.4	1.3
Long-snouted seahorse	82	69	140.9	1.7	88.5	71	109.5	1.2
Gurnard	80.3	70.8	142.7	1.8	84.5	73.4	110.4	1.3
Greater sandeel	80.3	70.8	142.7	1.8	84.5	73.4	110.4	1.3
Starry smooth hound	81.8	69	134.4	1.6	87.4	73	106.2	1.2

Table 8 Bootstrap of 2019 impingement data: geometric & arithmetic mean

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Total Abundance	**54866.2**	**24518.8**	**175639.1**	**3.2**	**126910.7**	**43585.1**	**241442.7**	**1.9**
Sprat	24779.4	8316.4	101554.4	4.1	60216.5	13672.9	107924.5	1.8
Sand smelt	12771.7	4147.5	30163.5	2.4	48299.8	18403.1	113421.8	2.3
Sand goby	1332.7	513.3	3346.4	2.5	6257.1	1684.3	16175.5	2.6
Clupeid indet	1823.1	669.6	7064.5	3.9	3267.7	1164.1	7254.6	2.2
Herring	233.9	66.7	445.8	1.9	1138.6	453.5	2526.4	2.2
Rock goby	1228.7	777.8	1562.9	1.3	1307.9	1021.6	1751.1	1.3
Bass	1041.5	522.5	1564.8	1.5	1135.4	792.5	1730.5	1.5
Poor cod	692	364.9	1402.8	2	969.2	478.5	2114	2.2
Transparent goby	665.6	156	1101.3	1.7	737.2	452.9	1144.9	1.6
Common goby	542.6	235.6	708.5	1.3	685.6	495.2	944.3	1.4
15-spined stickleback	608.7	315.7	746	1.2	619.1	489.6	791	1.3
Lesser-spotted dogfish	245.4	131.6	497.5	2	356.8	177.7	766	2.1
Greater pipefish	369.9	152.3	469.1	1.3	373.1	275.7	490.4	1.3
Grey gurnard	197.4	79.7	350.4	1.8	317.3	194.8	591.3	1.9
Bib	183.3	84.9	261.9	1.4	309.1	204.9	530.2	1.7
Snake pipefish	358	189.7	454.2	1.3	306.3	244.1	374.8	1.2
5-bearded rockling	278.6	146.1	388.7	1.4	284.8	199.6	449.3	1.6
Mullet indet.	132.1	59.7	293	2.2	246.8	131	415.6	1.7
Corkwing wrasse	107.6	67	256.9	2.4	211.7	102.8	326.6	1.5
Pollack	109.8	68.9	214.7	2	193	109.6	286.2	1.5
Painted goby	95.4	66.6	274.1	2.9	182.5	85.6	412.8	2.3
Black goby	95.3	68	244.7	2.6	180.2	104.2	334.5	1.9
Whiting	133.2	67.1	214.5	1.6	176	123.3	244.5	1.4
Dragonet (common)	167.8	86.4	253.4	1.5	173.7	133.1	246.1	1.4
European eel	127.5	68.5	194.5	1.5	156.7	116.5	210.9	1.3
Golden grey mullet	159.1	77.3	239	1.5	149.9	116.5	206.2	1.4
Plaice	159	137.2	225.7	1.4	135.6	113.2	172.1	1.3
Nilsson's pipefish	101.7	67.7	170.9	1.7	124.6	91.1	176	1.4
Butterfish	107	66	159.7	1.5	119.1	95.6	157.8	1.3
Flounder	104.3	67.9	156.4	1.5	111.7	92.6	139.9	1.3
Tub gurnard	90.7	68.3	172.4	1.9	111.7	83.9	163.4	1.5
Dab	91.6	69.6	163.3	1.8	114.4	86.1	162.9	1.4
Pogge	101.3	65.2	163	1.6	118.1	90.2	159.1	1.3
Lozano's goby	98.8	68	174.6	1.8	117.1	82.6	161.5	1.4
3-spined stickleback	97.4	64	154.4	1.6	108.6	85.8	139.6	1.3
Long-spined sea scorpion	83.9	71	176.3	2.1	101.6	78	161.9	1.6
Raitt's sandeel	85.4	69	177	2.1	106.7	78	164	1.5
Thin lipped grey mullet	83.6	71	149.5	1.8	93.7	78	132.9	1.4

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Ballan wrasse	84.8	69	150.5	1.8	96.6	78	141.7	1.5
Worm pipefish	88.7	69	156.4	1.8	101.4	76.7	140.2	1.4
Thick lipped grey mullet	82.5	67	169	2	98.2	69	138.7	1.4
Tadpole fish	81.1	69.6	172.4	2.1	93.7	71	140.9	1.5
Cod	80.8	70.7	140.9	1.7	85.9	74	109.4	1.3
Striped red mullet	80.8	70	140.9	1.7	85.9	74	109.4	1.3
Scad	85.9	67	140.8	1.6	93.7	69	109.4	1.2
2-spotted goby	82	69	140.5	1.7	88.4	74	109.2	1.2
Gobiidae	80.8	69.3	142.3	1.8	86	74	110.1	1.3
John dory	82	69	140.5	1.7	88.4	73	109.2	1.2
Shanny	80.8	70.3	142.3	1.8	86	74	110.1	1.3
Thornback ray	81.9	68	138.7	1.7	88.1	71	108.3	1.2
Pipefish indet	81.8	69	134.6	1.6	87.4	73.2	106.3	1.2
Montagu's sea snail	80.8	70	140.9	1.7	85.9	73.5	109.5	1.3
Dragonet (reticulated)	80.8	70.1	140.9	1.7	85.9	74	109.4	1.3

Table 9 Bootstrap of 2020 impingement data: geometric & arithmetic mean

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Total Abundance	**107527.8**	**63678.2**	**166823.4**	**1.6**	**133264.6**	**89029.4**	**209994.7**	**1.6**
Sand smelt	45493.5	28300.4	86892.5	1.9	56374.6	37968.7	101773.9	1.8
Sprat	21470.7	5846.1	47811.2	2.2	39099.7	15831.9	62488.7	1.6
Sand goby	11151.4	5282.6	32616.1	2.9	15794.9	6263.6	33671	2.1
Clupeid indet	4541.4	1453.6	8161.3	1.8	6722.4	2943.2	10101.8	1.5
Bass	2917.5	1737.9	5149.6	1.8	3353.4	1953	5379.8	1.6
Rock goby	2407.5	1417.5	3529.2	1.5	3232.5	2051.6	5273	1.6
Herring	409.7	117.4	1871.6	4.6	1440.6	336.3	3620	2.5
Common goby	1043.8	537.6	1256.5	1.2	995.5	797.8	1222.3	1.2
Corkwing wrasse	622.3	141.2	980.6	1.6	796.4	412.4	1220.2	1.5
Poor cod	379.6	207.5	777	2	611.3	290.4	1149.5	1.9
5-bearded rockling	543.9	218.1	740.6	1.4	705.7	475.5	1054	1.5
Lesser-spotted dogfish	532.6	306.7	743.8	1.4	580.7	411.6	904.8	1.6
Whiting	251.6	89.3	517.9	2.1	598.5	244.9	1490.6	2.5
Greater pipefish	479.5	185.3	592.1	1.2	513.6	406.7	635.4	1.2
Pollack	416.7	226.7	560.4	1.3	485.8	356.4	728.2	1.5
Grey gurnard	215.2	77.9	329	1.5	461.2	266	822.4	1.8
15-spined stickleback	434.3	176.3	547.3	1.3	452.5	316.3	577.9	1.3
Black goby	178.8	75	568.1	3.2	413.4	128.2	789.6	1.9
Snake pipefish	289.6	132.6	376.8	1.3	387.9	282.7	568.5	1.5
Painted goby	298.2	93.3	387.3	1.3	311	240.4	368.9	1.2

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Transparent goby	316.9	172.9	513.5	1.6	342.8	218.5	595.7	1.7
Bib	173.6	74	291.7	1.7	324.6	207.8	535.8	1.7
Long-spined sea scorpion	163.8	78.1	229.9	1.4	196.5	149.9	263.6	1.3
Golden grey mullet	118	73.7	194.1	1.6	181	127.2	296.4	1.6
Dragonet (common)	120	71	206.6	1.7	161.2	113.7	237.6	1.5
Butterfish	107.5	71.3	194.6	1.8	153.3	111	231.2	1.5
European eel	107.4	73.5	170.1	1.6	134.6	102.8	179.2	1.3
Worm pipefish	109.6	71.7	165.5	1.5	130.6	101.8	183.2	1.4
Nilsson's pipefish	93.5	72.8	159.5	1.7	114.8	90.7	158	1.4
Mullet indet.	84.1	71.6	201.4	2.4	103.5	78	173.6	1.7
3-spined stickleback	145.6	137.6	206.3	1.4	117	105.6	142.1	1.2
Gobiidae	91.9	71.1	176.6	1.9	117	85.7	184.3	1.6
Gadoid indet.	89.2	70.9	174.6	2	111	84.3	168.6	1.5
Shanny	87.7	71.3	160	1.8	105.1	83.2	154.3	1.5
Tub gurnard	82.6	74	149.9	1.8	90.7	78	127.9	1.4
Thin lipped grey mullet	83.1	73	149.6	1.8	92	78	130.2	1.4
Plaice	84.8	70.9	151.2	1.8	96.6	78	141.3	1.5
Dab	83.1	73	148.8	1.8	92	78	129.8	1.4
Lesser sandeel	85.8	69	139.3	1.6	93.3	75.1	108.7	1.2
Tompot blenny	83.1	73	151.6	1.8	92.5	78	129.7	1.4
John dory	83.6	72.8	155.5	1.9	93.9	78	133.3	1.4
Pipefish indet	80.5	72.5	173.6	2.2	90.7	74	141.7	1.6
Montagu's sea snail	85.8	69	139.3	1.6	93.3	74.1	108.7	1.2
Gilthead sea bream	80.8	72	139.3	1.7	85.7	74	108.7	1.3
Ballan wrasse	80.8	71.8	139.3	1.7	85.7	74	108.7	1.3
Pogge	82	71	141.1	1.7	88.5	74	109.6	1.2
2-spotted goby	82	70.3	143.3	1.7	88.9	73	110.7	1.2
Short-spined sea scorpion	80.3	73	141	1.8	84.3	74	109.5	1.3
Thornback ray	80.3	72.3	141	1.8	84.3	74	109.5	1.3
Wrasse indet	82	70	143.3	1.7	88.9	73.9	110.7	1.2
Gurnard	80.8	72	143.7	1.8	86.2	74	110.8	1.3
Tadpole fish	80.3	72.3	141.7	1.8	84.4	74	109.9	1.3
Smooth sandeel	80.3	72.8	141	1.8	84.3	74	109.5	1.3

Table 10 Bootstrap of 2021 impingement data: geometric & arithmetic mean

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Total Abundance	**88038.5**	**35433.2**	**252845.9**	**2.9**	**181232.7**	**66089.7**	**339295.7**	**1.9**
Sand smelt	33301.2	16412.2	95344.8	2.9	72383	29713.3	135666.9	1.9
Sprat	20836.8	3397.7	68347.1	3.3	55071.6	19077.4	112997.7	2.1

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Sand goby	11258.1	4142.3	111823.7	9.9	35793.8	5336.9	113094	3.2
Painted goby	1418.5	669.2	4354.8	3.1	2752	836.8	6691.6	2.4
Common goby	771.3	186.9	4407.5	5.7	2464.4	296.5	5841.9	2.4
Rock goby	1245.8	555.2	3464.4	2.8	2212.9	742.6	3726.5	1.7
Herring	623.2	137	3452.5	5.5	1914	224.1	3669	1.9
Clupeid indet	142.6	71.9	226.1	1.6	926.4	326.3	2691.5	2.9
15-spined stickleback	1046.9	606.8	1294.2	1.2	1106.2	879.4	1410.7	1.3
Poor cod	686.2	340.4	1773.3	2.6	962.8	474.9	2077.4	2.2
Lesser-spotted dogfish	563.5	129.2	875.6	1.6	771.4	424.3	1155.4	1.5
Pollack	655.9	406.3	1085	1.7	764.9	522.6	1380.8	1.8
Greater pipefish	529	211.7	736.9	1.4	747	487.1	1092.3	1.5
Golden grey mullet	473.8	224.4	832.3	1.8	645.5	371.7	1376.7	2.1
Bass	454.1	281.4	1065.3	2.3	518.9	295.6	1089.2	2.1
5-bearded rockling	393.4	170.7	694.7	1.8	529.6	284.2	988.6	1.9
Bib	408.4	206.9	872.2	2.1	487.2	198.5	897.5	1.8
Transparent goby	317.8	98.3	446.9	1.4	448.2	308.4	635.6	1.4
Snake pipefish	343.6	160.9	444.9	1.3	332	258.4	447.5	1.3
Long-spined sea scorpion	302	106.7	420.9	1.4	335.6	248.2	452.3	1.3
Thin lipped grey mullet	100	67.7	533.1	5.3	271	79.6	616.3	2.3
Grey gurnard	215.4	138.9	325.5	1.5	210.8	146.2	319.9	1.5
Black goby	159.8	73.6	228.1	1.4	215.1	157.5	303	1.4
Nilsson's pipefish	93.7	66	345.6	3.7	186.5	69	326	1.7
Whiting	110	67.7	193.2	1.8	150.1	105	244.7	1.6
Corkwing wrasse	116.4	67.9	204.3	1.8	165.1	115.4	237.1	1.4
Butterfish	116.2	65.8	185.7	1.6	153.3	113.5	211.5	1.4
Mullet indet.	112.6	64.2	190.8	1.7	139.3	99.9	192.7	1.4
Tub gurnard	89.1	67.9	325	3.6	140	77.7	295	2.1
Dragonet (common)	99.4	70.4	181.7	1.8	140.3	99.4	196.4	1.4
Gadoid indet.	84.9	71	317.2	3.7	127.6	77.1	295	2.3
Tompot blenny	96.6	68.8	181.9	1.9	132.7	93	185.5	1.4
European eel	102.6	67	174.8	1.7	126.7	92.8	193	1.5
Flounder	88.5	70	211.7	2.4	123.7	82	208.9	1.7
3-spined stickleback	96.7	68.7	178.7	1.8	122.2	90.4	177.5	1.5
Plaice	106.3	67.4	159.5	1.5	117.6	94.8	154.1	1.3
Scad	95.5	66	178.9	1.9	124.5	88.3	171	1.4
Shanny	93.6	70.8	166.9	1.8	113.7	87.9	162.3	1.4
Worm pipefish	90.8	71	163.1	1.8	107	81.7	149.3	1.4
Cod	80.5	71.6	168	2.1	90	74	138	1.5
Garfish	85.9	68.9	140	1.6	93.5	74.3	109	1.2
Thornback ray	84.7	69	149.7	1.8	95.8	78	139	1.5

Species	Geometric Mean				Arithmetic Mean			
	Estimated Annual Impingent	Lower Confidence Interval	Upper Confidence Interval	Ratio (UCI/EAI)	Annual	Lower Confidence Interval	Upper Confidence Interval	Ratio (UCI/EAI)
Striped red mullet	85.7	67	138	1.6	93	69	108	1.2
Lesser sandeel	82	70	140	1.7	88.3	73.7	109	1.2
2-spotted goby	80.8	70	140	1.7	85.7	74	109	1.3
Gobiidae	85.9	67	140	1.6	93.5	70	109	1.2
Sea lamprey	80.7	70	134	1.7	85	74	106	1.2
Short-spined sea scorpion	80.8	70.2	140	1.7	85.7	74	109	1.3
Thick lipped grey mullet	81.9	69	138	1.7	88	73	108	1.2
Dover sole	80.8	70.8	140	1.7	85.7	74	109	1.3
Goldsinny wrasse	80.8	70.8	140	1.7	85.7	74	109	1.3
Sea trout	82	70	140	1.7	88.3	74	109	1.2
Dragonet (indet)	81.9	69	138	1.7	88	73	108	1.2
Ling	80.8	70.7	140	1.7	85.7	74	109	1.3

Table 11 Bootstrap of 2022 impingement data: geometric & arithmetic mean

Species	Geometric Mean				Arithmetic Mean			
	Estimated Annual Impingent	Lower Confidence Interval	Upper Confidence Interval	Ratio (UCI/EAI)	Annual	Lower Confidence Interval	Upper Confidence Interval	Ratio (UCI/EAI)
Total Abundance	**97052.5**	**28583.5**	**181544.7**	**1.9**	**173995.8**	**92639.3**	**301059**	**1.7**
Sand smelt	29008.2	11786.7	65054.8	2.2	75522.1	33026.2	161256	2.1
Sprat	40841.1	1344.3	83847.7	2.1	63657.4	7767.5	92701.2	1.5
Sand goby	4898.6	1952.4	40794.7	8.3	15732.6	2462.7	42063.8	2.7
Rock goby	2392.9	1345.4	3639.6	1.5	3075.7	1987.3	4842.5	1.6
Greater pipefish	1832.9	460.3	3091.7	1.7	2462.8	1012.8	3660.3	1.5
Common goby	737.5	298.6	1217.7	1.7	1933.9	794.4	4257.6	2.2
Bass	948	312.1	2128.3	2.2	1662.6	632.2	2881.4	1.7
Transparent goby	1351.1	715.8	2364.2	1.7	1535.8	971.3	2570	1.7
Painted goby	712.8	297.3	3438.9	4.8	1564.8	458.6	3723.8	2.4
Mullet indet.	679.1	170.8	1379.9	2	1046.6	461.7	1917	1.8
Snake pipefish	593.6	92.5	842.7	1.4	864.5	543.2	1275	1.5
Herring	305.3	84	560.7	1.8	819.9	336.3	1752.2	2.1
Poor cod	444.1	191.6	725	1.6	586.9	333.7	1076.4	1.8
Golden grey mullet	656.4	407.3	845.3	1.3	597.7	427.2	800.9	1.3
15-spined stickleback	374.3	122.3	539.9	1.4	575.4	342	1028.2	1.8
Bib	379.4	111.3	778.2	2.1	515.5	285.5	955.7	1.9
Nilsson's pipefish	212.7	67.4	597.9	2.8	493	127.7	833.3	1.7
Lesser-spotted dogfish	325	78.3	458.7	1.4	428.9	289.1	675.3	1.6
Whiting	108.2	66	222.9	2.1	290.5	99.2	663.7	2.3
Pollack	221.5	94.1	397.9	1.8	273.3	165.9	485.7	1.8
Corkwing wrasse	122.1	66.7	307.1	2.5	269.5	120.2	565	2.1
Clupeid indet	118.6	64.8	241.1	2	237.8	137.6	432.3	1.8

	Geometric Mean				Arithmetic Mean			
Species	**Estimated Annual Impingent**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**	**Annual**	**Lower Confidence Interval**	**Upper Confidence Interval**	**Ratio (UCI/EAI)**
Worm pipefish	124.1	67	227.4	1.8	230	146	369.9	1.6
Long-spined sea scorpion	193.3	86.7	274.9	1.4	196.5	148.6	277.8	1.4
Flounder	105	69.2	306.2	2.9	181.1	99	343.3	1.9
Pilchard	89.3	66	270.9	3	175.4	78	370.1	2.1
Butterfish	174.5	84.6	251	1.4	174.2	134.3	230.2	1.3
5-bearded rockling	110.6	67.8	237.5	2.1	161.1	102.4	267.5	1.7
Striped red mullet	88.2	68	322.4	3.7	158.6	78	319.7	2
Grey gurnard	106.8	66.3	215.2	2	153.8	97.6	249.5	1.6
Black goby	95.5	68.1	238.2	2.5	153.1	93.6	271.8	1.8
3-spined stickleback	106.3	59	246.3	2.3	156.6	66	212.7	1.4
European eel	157.8	85.1	226.7	1.4	145.8	117.6	189.5	1.3
Thin lipped grey mullet	102.5	67.1	207.1	2	141.3	92.6	236.5	1.7
Dragonet (common)	91.4	68.3	244.5	2.7	141.9	84.4	253.2	1.8
Ballan wrasse	87.6	68.8	265.2	3	138.5	78	259.4	1.9
Plaice	98	67.9	157	1.6	109.9	81	141.5	1.3
Scad	85.9	69	151.3	1.8	98.7	78	140.1	1.4
2-spotted goby	86	68.8	154	1.8	99.1	78	141.3	1.4
Shanny	85.9	69	153.8	1.8	98.4	78	139.2	1.4
Thick lipped grey mullet	86	70	156	1.8	99.2	78	141.5	1.4
Dover sole	83.6	71.2	146.3	1.8	93.3	78	129.3	1.4
Tub gurnard	82	70	141	1.7	88.5	74	109.5	1.2
Gilthead sea bream	82	68.3	142.1	1.7	88.7	73.7	110	1.2
Lesser sandeel	82	69	142.1	1.7	88.7	74	110	1.2
Pogge	82	68.8	142.1	1.7	88.7	75	110	1.2
Tompot blenny	82	69	142.1	1.7	88.7	74	110	1.2
Gobiidae	80.8	70	140.2	1.7	85.8	74.4	109.1	1.3
Lesser weever	82	69	142.1	1.7	88.7	74	110	1.2
Lumpsucker	82	69	142.1	1.7	88.7	74	110	1.2
Goldsinny wrasse	82	69.8	140.2	1.7	88.4	71	109.1	1.2
Wrasse indet	80.8	70.3	138.4	1.7	85.6	74.6	108.2	1.3
Gurnard	82	69.3	141	1.7	88.5	74.9	109.5	1.2
Sea bream indet	82	69	142.1	1.7	88.7	74	110	1.2
Short-snouted seahorse	80.8	70	138.7	1.7	85.6	74	108.3	1.3
Spiny seahorse	82.1	68	145.3	1.8	89.2	72	111.7	1.3

7. Discussion and Conclusions

The estimated annual impingement and confidence interval derived by bootstrapping the survey data is tabulated above (Table 2 to Table 11). The annual estimate has been calculated in two ways. Firstly, as the sum of monthly arithmetic means and secondly using the monthly geometric means. The tables include the ratio of the upper (95%ile) confidence limit to the annual estimate as a measure of the uncertainty in the annual estimates used in the reporting.

The uncertainty ratio, expressed as the ratio of the upper confidence interval to the annual value, varies between species and years reflecting the underlaying variability in the survey data. In general the uncertainty is lower for the annual impingement calculated using an arithmetic mean. The typical ratio is about 1.6 for the annual impingement calculated from the arithmetic mean and 2.3 for the geometric mean. These values are generally similar to uncertainty levels in other impingement surveys of this nature at other power stations. There are some larger ratios (e.g. 9.9 in 2021) reported which are a result of catches that are outside of the normal degree of variation observed (e.g. a peak in sand goby abundance in a single survey in 2021).

The bootstrapping methodology allows for an assessment of the uncertainty in the number of fish impinged compared with the reported values. This approach allows for an estimation of the range within which the true annual impingement lies. The value of the impingement uncertainty analysis will depend on the ultimate use of the data. In the work by CEFAS for Hinkley Point C (HPC) (CEFAS, 2018) uncertainty analysis was used in the assessment of impingement as data from an existing station was being 'corrected' and scaled for a new station with a different operating regime. In this example, the calculated uncertainty can provide an indication of the variability that could be expected within the data for the new station when operational, and to allow a worst case to be assessed for the purpose of consenting.

Uncertainty in the context of the Pembroke data does provide the relative uncertainty in the impingement catches, as surveys are not undertaken every day of the year and an element of scaling is required. A difference between the HPC and Pembroke situations is that the Pembroke data is not being used in isolation to examine trends in fish populations, nor to assess the effect of abstraction at a future power station development. The data for Pembroke is assessed in the context of the full monitoring programme where populations in the Haven are also being monitored, and represents actual operational data. Therefore any potential effect of any uncertainty in the data is already being captured in the analysis of the wider fish communities.

The analysis completed across the monitoring programme is used to look for change within a population or community, where a change is observed looking to see if it is of statistical significance, and finally if it is of statistical significance looking to see if it is attributable to station operation or of ecological significance. Analysis for patterns of change within the data at both community level and individual species level is undertaken so that those species of conservation concern, or those that are abundant within the data can be assessed in more detail.

Fundamentally, the analyses undertaken to date have not shown any underlying trends of change that are of ecological significance (Jacobs 2023a). This highlights that irrespective of the uncertainty calculated within the impingement data, abstraction at Pembroke Power Station is not having a negative effect on local fish populations.

8. References

CEFAS (2018) Revised Predictions of Impingement Effects at Hinkley Point C Edition 2
HPC-DEV024-XX-000-RET-100031

CEFAS (2022) Hinkley Point B Comprehensive Impingement Monitoring Programme 2021 – 2022
TR573

Jacobs (2023a) Quantification of Entrapment Pressure
Document no: JUKL/B2386200/2021/R06

Jacobs (2023b) Pembroke Environmental Fish Survey Report 2021.
Document no. JUKL/B2386200/2021/R05

Jacobs (2024) Pembroke Abstraction Renewal Supporting information.
Arithmetic and Geometric Mean
Document no: JUKL/B2386202/LIC/R07