SPP111 Sizewell C impingement predictions corrected for Sizewell B raising factors and cooling water flow rates

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1	First release		M.B. & S.D.	04/03/2021
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Cefas

Sizewell C impingement predictions corrected for Sizewell B raising factors and cooling water flow rates

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Version and Quality Control

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Executive Summary

Direct cooled coastal power stations abstract large volumes of water to cool their condensers. Fish (and crustacea) are abstracted with the cooling water and are impinged on fine filtration systems (drum and/or band screens) that are designed to protect the condensers and other essential cooling water systems from blockage. Fish are washed off the screens and either returned to sea via a Fish Recovery and Return systems (e.g. at Sizewell B) or at older stations with no FRR systems, the fish are collected in waste bins for waste disposal. It is possible to intercept the flow of fish recovered from the screens via the use of sampling nets and this sampling forms the basis for impingement monitoring.

As part of the Development Consent Order (DCO) application for the operation of Sizewell C, EDF Energy has assessed the effects of cooling water abstraction on fish populations. The basis for predictions of impingement by Sizewell C are data collected at the operational Sizewell B station. Impingement monitoring at that station consisted of a total of 205 sample visits in the combined period February 2009 to March 2013, and April 2014 to October 2017. The adopted impingement sampling protocol is described in BEEMS Technical Report TR339; briefly the target for each sampling visit was to collect six hourly samples and an overnight bulk sample (18 hours). A valid overnight bulk sample sometimes could not be collected due to overflow of the sampling net due particularly to large numbers of ctenophores or sprat at certain times of the year or logistical issues at the station. In such cases, as the amount of material that overflowed could not be calculated, the monitoring protocol was that the bulk sample should not be included, and the 24-hour total should be extrapolated from the 6 hourly samples.

The Environment Agency requested further information on the treatment of bulk samples subject to overflowing and clarity on the methods used to raise impingement predictions to full operational capacity (EPR/CB3997AD/A001; Schedule 5 No.1 Additional Requests 3). The cooling water demands of Sizewell B are largely met by four Main Cooling Water (MCW) pumps and their associated four drum screens. In addition, there are two small cooling water feeds, Auxiliary Cooling Water (ACW) and Essential Cooling Water (ECW) with their own pump systems. All of the cooling water at Sizewell B is filtered through the drum screens. The number of MCW pumps varies according to need throughout the year, but the ACW and ESW demand is essentially constant (except during maintenance periods). Under normal operational conditions, the number of pumps determines the number of operational drum screens. However, this is not always the case and in some instances between 2009-2017, raising factors applied based upon the number of operating screens (rather than MCW pumps) has led to errors in the raising factors to calculate impingement during full operating capacity. It was also found that in the period 2009 to 2013, overflowing bulk samples had been included in the 24-hour impingement estimates rather than removed from the data set.

The raising factors were corrected, and the overflowed bulk samples were removed from the dataset. To ensure that the Sizewell B impingement estimates were as accurate as possible, and after discussion with the station's engineering staff, the previously assumed nominal cooling water flow rates were replaced with actual flow rates under the different operational conditions. Revised unmitigated impingement estimates have been prepared for SZB and an unmitigated SZC.

Updates in Version 2 of this report:

Commenting on version 1 of this report the Environment Agency requested further clarification through Schedule 5 No.4.

Schedule 5 No.4 Additional Requests 3 and 4 are specifically addressed in this report. In summary, the Additional Requests sought further clarification of whether pumps or screens were used to raise the impingement rates on the three occasions where there were discrepancies between 2014-2017 This information request is considered in Section 2.2.

The Environment Agency requested further information on the apparent differences between the proportion of invalid bulk samples between 2009-2013 and 2014-2017, with the latter having a greater proportion of overflowing bulks. This information request is considered in Section 2.1.

Following revisions based on Environment Agency comments, this report provides revised impingement estimates for SZB and predictions for SZC. To allow full transparency the results presented in Section 3 herein are compared to those originally provided for SZB in BEEMS Technical Report TR339.v3 and for SZC in BEEMS Technical Report TR406.v7. A comparison between version 1 and this report is also provided in Appendix B.2.

Conclusions

1. Removal of the invalid bulk samples, correction of pump raising factors and refinement in station flow rates resulted in small changes in estimated Sizewell B impingement for most species. Changes were species specific, the eight species contributing to the top 95% of impingement saw a mean decrease of 1.8% compared to the results presented in BEEMS Technical Report TR339.v3.

2. The removal of the additional bulk samples in version 2 of this report had a very minor influence of the impingement predictions for most species. The eight species contributing to the top 95% of impingement saw a mean annual increase of 0.7% compared to the results in version 1.

3. The use of an underestimated nominal value of cooling water flow at full cooling capacity for Sizewell B also resulted in an overestimate for Sizewell C impingement.

4. The final corrected impingement predictions for Sizewell C resulted in a mean decrease for the eight species contributing to the top 95% of 10.8% compared to figures presented in BEEMS Technical Report TR406.v7.

5. Of the 24 key fish species, only cod and smelt showed an increase in predicted impingement and then by 0.5% and 6.6%, respectively. A single allis shad was impinged on the 28th May 2009 in an invalid bulk sample, meaning impingement predictions are not available for the species. However, impact assessments will continue to consider the species as present and acknowledge its occurrence in the impingement record.

6. The corrections to the raising factors, removal of invalid bulk samples and refinement of the cooling water flow rates serves to improve the accuracy of the Sizewell C impingement predictions. However, the small changes in mean impingement predictions are well within the original confidence intervals and do not change the overall outcome of the impingement assessment effects when assessed against relevant spawning stock biomass (SSB) or landings comparators. **The corrections to impingement predictions presented in this report therefore do not materially alter the conclusions of the SZC DCO assessment.**

1 Background

EDF Energy plans to build a new coastal nuclear power station (Sizewell C), adjacent to the operational Sizewell B and decommissioned Sizewell A sites in Suffolk. The station will be of a once-through design, abstracting large volumes of seawater for cooling the condenser steam. Water abstraction can lead to the impingement of fish. As part of the Development Consent Order (DCO) application for the operation of the new station, EDF Energy is required to evaluate the effects of water abstraction on fish. Impingement predictions for both Sizewell B (SZB) and Sizewell C (SZC) have been calculated from impingement monitoring at SZB.

1.1 Impingement sample methodology

The basis for predictions of impingement by SZC are data collected at the operational SZB station. Between February 2009 and March 2013, and again from April 2014 until October 2017 impingement sampling (known as the Comprehensive Impingement Monitoring Programme, CIMP) was undertaken at SZB. The sample methodology is provided in BEEMS Technical Report TR339 v3. The sampling target was to collect a 24-h sample on each station visit by taking seven samples:

- six samples of one hour each during daylight hours, and;
- one 18-h bulk sample.

Between February 2009 and March 2013, impingement sampling was carried out at SZB by Pisces Conservation Ltd (hereafter, Pisces), as part of the BEEMS programme. A total of 128 sample visits were completed collecting data on the number and weight of fish, invertebrates and other material impinged by the station cooling water drum screens. Following quality assurance by Pisces, summary Excel worksheets containing raised estimates of 24h impingement together with the raw data sheets were provided to Cefas.

Impingement monitoring resumed in April 2014 until October 2017 and was completed by Cefas. During this period 77 sample visits were completed. Cefas samples were collected on site using Electronic Data Capture (EDC) software. Once back in the lab the data was transferred to Cefas' Fish Survey System (FSS) and quality assured by the Scientist in Charge (SIC).

In total 205 sample visits were achieved at SZB. The data from each sample visit is treated to determine the 24-hour impingement estimates raised to full station operating capacity. This process is achieved based on the following considerations:

- To raise the sampling to 24 hours, the six hourly samples and the 18-hour bulk are combined accounting for the exact duration of each sample. Restricted access at operational power stations means it is not possible to monitor the collection of bulk samples overnight. In some cases, this resulted in bulk samples overflowing. Overflowing bulk samples have been discarded and 24-hour estimates are based on scaling up the hourly samples.
- The station does not always run at full cooling water capacity and may have less than four pumps in operation. Using the appropriate multiplication factor, data have been raised to represent a 24-h sample at full operational pumping capacity.

The two data series are then combined to determine estimates of annual impingement using a statistical bootstrapping approach (BEEMS Technical Report TR339). By determining annual impingement at SZB based on full operational cooling water capacity throughout the year, the predictions are precautionary.

The Environment Agency have requested additional information regarding overflowing bulk samples during the Pisces' sampling years and further information on the method of raising the impingement rates to full operating capacity (Section 1.2).

1.2 Environment Agency Schedule 5 request

On the 22nd December 2020, EDF Energy received comments from the Environment Agency on the SZC operational WDA environmental permit application (EPR/CB3997AD/A001; Schedule 5 No.1 Additional Requests 3).

The Additional Requests were:

1. *To allow us to progress our SZB impingement audit, please provide a list of those PISCES 2009 to 2013 surveys effected by overflowed bulk samples, and where estimates have been made using data from hourly samples alone.*
2. *It is unclear from the information provided to date how the calculation to raise SZB impingement survey data to full capacity has been made. Therefore, please provide the following additional information and clarification:*
    a) *Please clarify and confirm in writing how the method/calculation to raise SZB impingement survey data to full capacity has been made.*
    b) *Assuming that the method/calculation is based on the number of operational pumps, please confirm in writing the number of pumps working for each of the Cefas 2014-2017 surveys.*

The purpose of this report is to address the Environment Agency Schedule 5 comments.

Revision 1 of this report addressed issues relating to raising factors and identified and removed 27 overflowing bulk samples from the data set. Flow rates, used to scale impingement to full operational capacity was also refined after discussion with the station's engineering staff, resulting in the previously assumed nominal cooling water flow rates at SZB being replaced with actual flow rates under the different operational conditions. Unmitigated impingement estimates were then prepared for SZB and SZC.

In reviewing version 1 of this report, the Environment Agency requested additional information. Two of these requests are addressed directly in this report. The Environment Agency sought further clarification of whether pumps or screens were used to raise the impingement rates on the three occasions where there was a discrepancy during between 2014-2017 (Schedule 5 No.4 Additional Requests 3). Responses to these comments were provided through the Schedule 5 and are detailed in Section 2.2.

The Environment Agency also questioned the apparent differences between the collection of bulk samples between the Pisces years and the Cefas years, with the latter having a greater proportion of overflowing bulks (Schedule 5 No.4 Additional Requests 4). This information request is considered in Section 2.1.

Following revisions based on Environment Agency comments, this report provides revised impingement estimates for SZB and predictions for SZC. To allow full transparency the results presented in Section 3 herein are compared to those originally provided for SZB in BEEMS Technical Report TR339.v3 and for SZC in BEEMS Technical Report TR406.v7. A comparison between version 1 and this report is provided in Appendix B.2.

Other Environment Agency Schedule 5 No.4 comments have been addressed through Schedule 5 responses.

Raw data sheets have been provided to the Environment Agency in conjunction with this report.

2 Corrections to input data and flow rates

2.1 Overflowed bulk samples

Impingement monitoring personnel cannot remain on the site outside normal working hours due to site security restrictions. Restricted site access at operational nuclear power stations means it is not possible to monitor overnight bulk samples.

Bulk samples may overflow when the sample net become clogged. In summer months overflow typically arises due to large numbers of ctenophores clogging the nets. Overflows may also result due to ingress of weed and/or mud, or in the winter months due to inundation of pelagic species, primarily sprat and herring, and demersal whiting.

A bulk sample is considered invalid if water overflows over the top of the trash bins, as this could potentially result in underestimates of the sample. Bulk samples left to run overnight may be diverted by station staff, either if they have already overflowed or overflow appears likely. If the water has been shut off by the station overnight, the SIC observes the “pit” to see if any fish are present outside the net. If there are fish present, then the sample is deemed invalid. On only four occasions when the station redirected the flow during Cefas years, were the samples confirmed as valid and used in the assessments.

Invalid bulk samples should be removed from the analyses. When bulk samples are invalid, hourly samples are applied to estimate 24-h impingement.

Invalid bulk samples in the Cefas data series were provided in BEEMS Technical Report TR339.v3 and in Appendix A. In total 70 bulk samples were set between April 2014 and October 2017. On 49 occasions (70%) the bulk was deemed invalid and removed from the analyses. There were seven occasions (10%) when the bulk sample was not set due to operational reasons.

The Environment Agency requested details of the occurrence of overflowing bulk samples during the Pisces data period. During the Pisces’ sampling years (2009-2013) there were four occasions where no bulk sample was collected, and hourly samples were raised to account for the missing bulk (Table 1).

Version 1 of this report removed 27 occurrences where bulk samples had overflowed identified by notes in the data sheets (Table 1). Following the Schedule 5 No.4 Additional Requests 4 from the Environment Agency (Section 1.2), a further review of the data has been undertaken. Any sample where the flow was redirected or may have overflowed has been treated as invalid and removed from subsequent analyses. This results in a total of 45 occasions when the bulk has been removed or 36% of the 124 deployed bulk samples during the Pisces data series (Table 1). On four occasions a bulk was not set (3%).

Despite identification of additional overflowing bulk samples, the successful deployment of bulk samples was approximately double in the Pisces years. Why is this the case?

A contributing factor leading to the difference in the proportion of bulks, which have overflowed is the time of year that the bulks were deployed. Due to station outages in Q4 2014 and Q1 2015, 63% of Cefas samples were being collected during Q2 and Q3. These periods, particularly Q3 when 25/70 of the bulk samples were deployed, are prone to the highest proportion of invalid bulks due to ctenophore and gelatinous zooplankton ingress. During periods of very high ctenophore biomass, fish impingement numbers are typically low (Figure 3 in BEEMS Technical Report TR406.v7). There are no annual or seasonal trends in ctenophore biomass over the monitoring period, however, spikes in ctenophore biomass were recorded in 2014 and 2015, during the Cefas years (Appendix B.3; Figure 1). Quarter 3 in 2016, and to a lesser degree in 2017, corresponded with large spikes in jellyfish (seasonal trends in jellyfish weight in Q3 between 2009-2017 were not significant; tau 0.42, p = 0.14, Theil-Sen slope = 4,873 [1]).

Annual sprat numbers have not shown a trend throughout the impingement monitoring period, but herring increased markedly between 2009-2017 (tau 0.86, p <0.01, Theil-Sen slope = 115,542) and whiting also increased annually, although this was not significant at α 0.05 (tau 0.57, p = 0.06, Theil-Sen slope = 50,497). The increases in two of the three most abundant species may also have contributed to more samples overflowing in Q1 during the Cefas years.

It is not possible *a posteriori* to determine the extent to which the seasonal sampling strategy or changes in the abundance of species leading to overflows contributed to the differences in the proportion of invalid bulk samples between the Pisces and Cefas years. However, a total of 100 valid bulk samples contribute to the impingement data series (21 in Cefas years, 79 in Pisces years). Any sample potentially subject to overflowing has been removed. Importantly, the effects of removing the additional bulk samples between version 1 and this report resulted in minimal changes in the predicted SZC impingement predictions for most species (Appendix B.2). We can therefore be confident in the data used for impingement predictions.

2.2 Pump and screen corrections

Power station operational variables are recorded for each sampling visit including the number of pumps running and the number of drum screens in operation. Typically, the number of pumps in operation determines the number of drum screens in use, however, this is not always the case. As pumping capacity determines the volume of water being screened, the number of operational pumps should be applied to raise impingement to full operating capacity.

When SZB is not operating at full cooling water pumping capacity, the formula used to raise the data used the following equation:

$$Full\ capacity\ impngement = observed\ impingement \times \frac{Full\ pumping\ capacity\ (4\ pumps)}{Number\ of\ operational\ pumps}$$

Equation 1

Equation 1 was applied for each species when only two or three pumps are operating, giving 24-hour impingement raising factors of 2 and 1.333, respectively. This formula is a simplified approximation and in reality, it overestimates the cooling water flow when the number of pumps is less than four (see Section 2.3).

During the period 2009-2013, impingement rates at full capacity were raised based on the number of screens rather than pumps operating. As such, occasions where the number of pumps and screens are not consistent led to errors in scaling factors, this is detailed in Section 2.2.1.

During the period 2014-2017 the approach to raising impingement estimates to full operating capacity was also based on the number of screens reported during monitoring. The number of screens was consistent with the number of pumps on all but three occasions. On occasions where the number of pumps and screens were not consistent errors in scaling factors occurred, this is detailed in Section 2.2.2.

2.2.1 Pump and screen corrections between 2009-2013

In their detailed comments the Environment Agency noted that the Pisces data (2009-2013) had been raised based on the number of operational screens rather than pumps.

To establish pumping rates, station flow data provided in the Pisces reports has been cross-checked against the reported number of pumps and screens in the raw data sheets. On 23 of 128 sampling occasions the

[1] Kendall's tau statistic measures the rank correlation between impingement and year (with a range from -1 to +1, with 0 when there is no correlation), the 2-sided *p*-value is from the Mann-Kendall test. The Theil-Sen slope estimate is a median slope estimate for a linear change in impingement per year.

number of pumps and screens used to raise the data are not consistent (Table 1). On 19 occasions this has resulted in raising factors underestimating the total number of impinged fish (more operational screens than pumps), and on 4 occasions impingement numbers have been overestimated (more operational pumps than screens).

Revised impingement estimates are provided in Section 3.

2.2.2 Pump corrections between 2014-2017

Data during the Cefas sampling years (2014-2017) was previously raised based on the number of operational screens reported by the impingement monitoring team on site on the assumption that the number of operational pumps and screens was consistent. Additional cross-checks indicated that on three of the 77 sample occasions during this period, the number of screens reported by monitoring staff (and assumed to be pumps) was inconsistent with the number of operational pumps. On these three occasions the raising factor was incorrectly applied. These were:

- 15th June 2017;
- 2nd July 2017; and,
- 26th July 2017.

On each of these occasions, the station was operating at full capacity (4 pumps) whereas the data was erroneously raised based on the assumption of 3 operational pumps (the number of screens reported). Impingement numbers on these dates were overestimated.

This error has been corrected and raised to the equivalent flow rate based on the number of operational pumps (Section 2.3), revised impingement estimates are provided in Section 3. Details of the Cefas samples including invalid bulk samples and corrections to the number of operational pumps is provided in Appendix A.

SPP111 Sizewell C impingement predictions corrected for Sizewell B raising factors and cooling water flow rates

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Table 1. Identification of data raising errors for full operational pumping capacity and invalid bulk samples in between 2009-2013. Samples highlighted in blue show invalid bulk samples, invalid samples underlined represent the additional samples identified in this report. All invalid samples have been removed from analyses. The consequence of overflowing bulks is hourly samples are used to calculate 24-hour impingement estimates. Orange highlighted cells indicate sample visits where the raising factor underestimated impingement rates at full capacity, whereas yellow cells indicate sample visits where the raising factor overestimated impingement rates at full capacity. All errors have been corrected in the impingement predictions presented herein. Dates provided represent the second day of each sampling visit.

Sampling visit	Reported screens (applied raising factor)	Calculated number of pumps based on flow rates (corrected raising factor)	Consequence	Bulk
2009				
04/02/2009	4	3	Underestimate	-
17/02/2009	4	3	Underestimate	-
18/02/2009	4	3	Underestimate	-
05/03/2009	3	3	-	-
24/03/2009	4	3	Underestimate	-
26/03/2009	4	3	Underestimate	-
31/03/2009	4	3	Underestimate	-
16/04/2009	4	3	Underestimate	-
21/04/2009	3	3	-	-
29/04/2009	3	3	-	-
14/05/2009	3	3	-	-
27/05/2009	3	3	-	-
28/05/2009	3	3		Invalid
04/06/2009	4	4	-	-
17/06/2009	4	4	-	Invalid
18/06/2009	4	4	-	-
02/07/2009	4	4	-	Invalid
09/07/2009	4	4	-	-
29/07/2009	4	4	-	-
30/07/2009	4	4	-	-
04/08/2009	4	4	-	Invalid
11/08/2009	4	4	-	Invalid
18/08/2009	4	4	-	Invalid
27/08/2009	4	2	Underestimate	-
03/09/2009	3	3	-	-
04/11/2009	3	3	-	-
05/11/2009	3	3	-	-
10/11/2009	3	3	-	-
11/11/2009	3	3	-	-
17/11/2009	3	3	-	-
25/11/2009	3	3	-	-
26/11/2009	3	3	-	-
03/12/2009	3	3	-	-
15/12/2009	3	3	-	No bulk sample
22/12/2009	3	3	-	Invalid
23/12/2009	3	3	-	-
2010				
12/01/2010	3	3	-	Invalid
19/01/2010	3	3	-	No bulk sample
03/02/2010	4	4	-	Invalid
04/02/2010	3	3	-	No bulk sample
17/02/2010	3	3	-	Invalid
18/02/2010	2	3	Overestimate	Invalid
02/03/2010	3	3	-	Invalid

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Sampling visit	Reported screens (applied raising factor)	Calculated number of pumps based on flow rates (corrected raising factor)	Consequence	Bulk
18/03/2010	3	3	-	No bulk sample
07/04/2010	2	2	-	Invalid
15/04/2010	2	2	-	Invalid
29/04/2010	2	2	-	-
12/05/2010	2	2	-	-
13/05/2010	2	2	-	-
25/05/2010	2	2	-	-
22/07/2010	2	2	-	-
28/07/2010	3	2	Underestimate	-
19/08/2010	3	2	Underestimate	-
25/08/2010	3	2	Underestimate	-
09/09/2010	3	2	Underestimate	-
17/09/2010	3	3	-	-
29/09/2010	3	3	-	-
08/10/2010	3	4	Overestimate	-
20/10/2010	4	4	-	Invalid
27/10/2010	4	4	-	-
28/10/2010	4	4	-	-
03/11/2010	4	4	-	Invalid-
10/11/2010	4	4	-	-
25/11/2010	4	3	Underestimate	-
08/12/2010	4	3	Underestimate	-
09/12/2010	4	3	Underestimate	Invalid-
16/12/2010	4	3	Underestimate	-
		2011		
07/01/2011	4	3	Underestimate	-
19/01/2011	4	3	Underestimate	-
20/01/2011	4	3	Underestimate	Invalid
26/01/2011	3	3	-	-
27/01/2011	3	3	-	-
02/02/2011	3	3	-	Invalid
25/02/2011	3	3	-	Invalid
17/03/2011	3	3	-	-
31/03/2011	3	3	-	Invalid
07/04/2011	3	3	-	-
27/04/2011	3	3	-	-
06/05/2011	3	3	-	-
18/05/2011	3	3	-	-
15/06/2011	4	4	-	Invalid
29/06/2011	4	4	-	Invalid
07/07/2011	3	3	-	Invalid
27/07/2011	4	4	-	Invalid
05/08/2011	4	4	-	Invalid
16/08/2011	4	4	-	Invalid
25/08/2011	4	4	-	Invalid
19/10/2011	3	3	-	-
20/10/2011	3	3	-	-
27/10/2011	3	3	-	-
10/11/2011	3	3	-	-
17/11/2011	3	3	-	-
23/11/2011	3	3	-	-
07/12/2011	3	3	-	-
14/12/2011	3	3	-	-
		2012		
12/01/2012	3	3	-	Invalid

Sampling visit	Reported screens (applied raising factor)	Calculated number of pumps based on flow rates (corrected raising factor)	Consequence	Bulk
02/02/2012	3	3	-	-
22/02/2012	3	3	-	Invalid-
01/03/2012	3	3	-	-
22/03/2012	2	2	-	Invalid
04/04/2012	3	3	-	Invalid
17/04/2012	3	3	-	-
03/05/2012	3	3	-	-
15/05/2012	3	3	-	Invalid
22/05/2012	3	3	-	-
13/06/2012	3	3	-	Invalid
20/06/2012	3	4	Overestimate	Invalid
04/07/2012	4	4	-	Invalid
26/07/2012	4	4	-	Invalid
02/08/2012	4	4	-	Invalid
16/08/2012	4	4	-	Invalid
21/08/2012	4	4	-	Invalid
13/09/2012	4	4	-	-
27/09/2012	4	4	-	Invalid
04/10/2012	3	3	-	Invalid
17/10/2012	3	4	Overestimate	Invalid
25/10/2012	4	4	-	-
07/11/2012	3	3	-	Invalid
21/11/2012	3	3	-	-
05/12/2012	3	3	-	Invalid
13/12/2012	3	3	-	-
2013				
09/01/2013	3	3	-	-
23/01/2013	3	3	-	-
06/02/2013	3	3	-	-
13/02/2013	3	3	-	-
20/02/2013	3	3	-	-
06/03/2013	3	3	-	-
26/03/2013	3	3	-	-
Total			**Underestimate 19** **Overestimate 4**	**Invalid 45** **No Bulk 4**

2.3 Sizewell B flow rate correction

During normal operational conditions, the number of Main Cooling Water (MCW) pumps determines the number of operational screens. Further operational information was sought from the Sizewell B station engineers to elucidate occasions where differences in the number of operational pumps and screens occurred.

Impingement predictions for SZB have been scaled up to full operational capacity based on the nominal figure of 51.5 $m^3 s^{-1}$ (cumecs) provided by the SZB station in 2010 to represent the average cooling water flow rate with four MCW pumps operating. When the station is operating at reduced capacity, with either three or two pumps operating, 24-hour impingement estimates have been raised to full operating capacity by applying Equation 1. However, in addition to the MCW, two additional flows are abstracted: the essential services water (ESW) and the Auxiliary Cooling Water (ACW). As with the MCW flow, these small volume flows are screened through the drum screens. The ESW and ACW flow rate is not reduced when the number of MCW pumps is reduced. Therefore, the application of Equation 1 to raise impingement rates to full operating capacity results in underestimated cooling water flow rates and overestimated impingement at full capacity.

The estimated total flow a full operational capacity is 56.7 cumecs. During the 205 sample visits full operational capacity with four pumps running occurred 40% of the time.

When three pumps are operating the volume of water screened is approximately 46.7 cumecs. Based on Equation 1, the applied correction factor to raise observed impingement to full operational capacity overestimates impingement by 9.8%. The station ran on three pumps during 54% of sample visits.

In the much less common case of two pumps operating, estimated flow rates are 31.5 cumecs and impingement estimates using a raising factor of 2, overestimate impingement at full capacity by 11.1%. However, two pumps operated on just 6% of sample visits.

Typically, the station operates at full capacity during the summer months and reduced capacity during the cooler winter months when the ambient seawater has greater cooling capacity (Table 1 and Appendix A).

The greater available detail on the existing Sizewell B flow rates has enabled refinement of impingement predictions when the station is not operating at full capacity (60% of sample visits). This additional refinement has been incorporated into the impingement assessments for Sizewell B.

2.3.1 Raising from Sizewell B to Sizewell C

Sizewell C impingement predictions are based on raising impingement estimates from Sizewell B to the greater abstraction volume of Sizewell C (131.86 cumecs) based on the equation:

$$Sizewell\ C\ impingement = \text{Sizewell B impingement } \times \frac{131.86\ cumecs}{56.7\ \text{cumecs}}$$

Equation 2

Equation 2 has been modified to account for the correct volume screened during full operational capacity. The Sizewell B to Sizewell C raising factor has thereby been reduced by 10% from 2.560 to 2.326.

In Section 3, all impingement predictions for Sizewell C are provided with invalid bulks and pump rate errors corrected with refined flow rate information. Table 2 provides a comparison with the previous impingement estimates for Sizewell B reported in BEEMS Technical Report TR339.v3, and Table 3 provides a comparison between corrected Sizewell C predictions and those presented in BEEMS Technical Report TR406.v7.

3 Results & Discussion

3.1 Sizewell B impingement predictions corrected for data raising errors and flow rates

Changes in impingement due to the correction of sampling raising factors are species specific. Eight species account for the top 95.1% of impingement by numbers at SZB, these include sprat, herring, whiting, bass, sand gobies, Dover sole, anchovy, and dab.

For most species' correction of the pump raising factor, removal of invalid bulk samples and refinement of flow rates resulted in impingement estimates increasing. The mean decrease for species contributing to the top 95% of impingement is 1.8% (Table 2). However, differences were species specific with sand gobies, smelt and cod seeing slight increases in estimated impingement at SZB in comparison with previous estimates in BEEMS Technical Report TR339.v3 (Table 2).

Impingement rates for the full species list is provided in Appendix B.1.

A noteworthy change was Allis shad, where the single individual impinged during the 205 sample visits was recorded in an invalid bulk sample, and thus removed from the data series.

As noted in Section 2.3, the station does not operate at full pumping capacity throughout the year. The mean number of pumps operating during all 205 sampling visits was 3.3, which when raised accordingly to full operational capacity for 365 days per annum represents a worst-case estimate for SZB.

Table 2. Annual unmitigated Sizewell B impingement estimate at full operational capacity. Raw impingement numbers are compared with TR339.v3 and following correction of invalid bulk samples and pumping raising errors and application of flow rate refinement.

Common name	Sizewell B impingement estimates (TR339 version 3)			Sizewell B Corrected for pumps and bulk sample raising errors and refined flow rates			Difference in mean (% change)
	Mean	Lower	Upper	Mean	Lower	Upper	
Sprat	2,703,033	1,427,342	4,549,040	2,646,189	1,364,820	4,478,852	-2.1
Herring	1,018,211	598,405	1,550,795	951,056	563,376	1,441,666	-6.6
Whiting	650,479	452,300	888,210	642,935	471,160	840,402	-1.2
European seabass	276,943	124,683	500,639	275,802	127,651	478,914	-0.4
Sand goby	196,545	81,220	383,493	207,900	88,386	394,005	5.8
Dover sole	91,370	63,510	125,792	90,766	62,984	125,047	-0.7
Anchovy	69,058	18,123	166,131	63,783	18,703	153,465	-7.6
Dab	56,054	33,869	93,069	55,245	32,813	92,227	-1.4
Thin-lipped grey mullet	49,751	13,394	97,783	46,269	14,356	89,305	-7.0
Flounder	14,569	10,943	19,251	13,824	10,478	18,151	-5.1
Plaice	9,653	6,328	14,355	9,441	6,078	14,071	-2.2
Smelt	8,122	5,405	11,295	9,531	5,963	13,919	17.3
Cod	6,415	2,440	11,433	7,097	2,458	13,247	10.6
Thornback ray	2,913	1,808	4,292	2,881	1,794	4,228	-1.1
Eel	1,184	762	1,719	1,059	658	1,560	-10.6
Twaite shad	1,168	574	2,036	1,158	576	2,017	-0.9
River lamprey	1,144	630	1,932	1,121	615	1,889	-2.0
Horse mackerel	695	220	1,715	671	210	1,615	-3.5
Mackerel	185	17	502	119	6	394	-35.7
Tope	27	0	106	24	0	89	-11.1
Sea trout	4	0	23	3	0	20	-25.0
Sea lamprey	2	0	11	2	0	11	0.0
Allis shad	1	0	8	0	0	0	-100.0
Salmon							

3.2 Sizewell C impingement predictions

Changes in impingement due to the correction of data raising errors and flow rate refinements are species specific. In all cases, with the exception of cod and smelt, impingement rates decrease compared to those presented in BEEMS Technical Report TR406.v7 (Table 3). The mean decrease for the eight species contributing to the top 95.1% of impingement is 10.8%.

The differences in predicted impingement at SZC between version 1 of this report and those provided in Table 3 herein are very minor, 0.7% for the eight species contributing to the top 95.1% of impingement (Appendix B.2). The only key species where changes in impingement rates were more than 2% in either direction was smelt, which saw a 8.4% increase above numbers predicted in version 1.

3.2.1 Implications for impingement assessments

The corrections to the raising factors, removal of invalid bulk samples and refinement of the cooling water flow rates served to improve the accuracy of the Sizewell C impingement predictions. Of the key species, the only notable change was Allis shad where a single impinged fish on the 28th May 2009 occurred in an invalid bulk sample (Table 1). The removal of this individual resulted in annual predictions reducing from 3 fish per annum at Sizewell C (Table 3) to 0 fish. However, impact assessments will continue to recognise an individual was impinged and consider the presence of the species.

The refined assessment results in small changes in mean impingement predictions with mean numbers well within the original confidence intervals. The results do not change the overall outcome of the impingement effects assessed against relevant spawning stock biomass (SSB) or landings comparators.

It should be noted that the principal parameters that materially influence effects predictions are the effectiveness of mitigation measures, the application of appropriate equivalent adult values (EAV), and the relevant scale of the stock or population comparator. Such considerations are beyond the scope of this data report and are considered in greater detail in BEEMS Technical Report TR406.v7.

The corrections to impingement predictions presented in this report therefore do not materially alter the conclusions of the SZC DCO assessment.

Table 3. Annual unmitigated Sizewell C impingement predictions at full operational capacity. Raw impingement numbers are compared with TR406.v7 and following correction of invalid bulk samples and data raising errors and application of flow rate refinement.

Common name	Sizewell C impingement numbers (TR406.v7)			Sizewell C Corrected for screens and bulk sample errors and refined flow rates			Difference in mean (% change)
	Mean	Lower	Upper	Mean	Lower	Upper	
Sprat	6,920,815	3,654,550	11,647,309	6,153,906	3,173,989	10,415,898	-11.1
Herring	2,607,016	1,532,149	3,970,636	2,211,750	1,310,172	3,352,700	-15.2
Whiting	1,665,479	1,158,064	2,274,163	1,495,192	1,095,717	1,954,416	-10.2
European seabass	709,082	319,238	1,281,830	641,398	296,862	1,113,750	-9.5
Sand goby	503,232	207,954	981,891	483,487	205,548	916,287	-3.9
Dover sole	233,942	162,609	322,077	211,083	146,474	290,806	-9.8
Anchovy	176,816	46,401	425,360	148,332	43,495	356,894	-16.1
Dab	143,519	86,719	238,293	128,476	76,309	214,481	-10.5
Thin-lipped grey mullet	127,382	34,295	250,361	107,602	33,386	207,685	-15.5
Flounder	37,303	28,018	49,291	32,149	24,367	42,211	-13.8
Plaice	24,716	16,202	36,755	21,956	14,135	32,723	-11.2
Smelt	20,795	13,840	28,921	22,165	13,867	32,370	6.6
Cod	16,426	6,248	29,272	16,505	5,716	30,807	0.5
Thornback ray	7,460	4,629	10,989	6,700	4,172	9,833	-10.2
Eel	3,031	1,951	4,402	2,463	1,530	3,628	-18.7
Twaite shad	2,989	1,470	5,213	2,693	1,340	4,691	-9.9
River lamprey	2,929	1,614	4,946	2,607	1,430	4,393	-11.0
Horse mackerel	1,779	564	4,391	1,560	488	3,756	-12.3
Mackerel	473	43	1,287	277	14	916	-41.5
Tope	70	0	271	55	0	207	-21.4
Sea trout	10	0	58	8	0	48	-20.0
Sea lamprey	5	0	29	4	0	26	-20.0
Allis shad	3	0	21	0	0	0	-100.0
Salmon							

4 References

BEEMS Technical Report TR339.v3. Cefas Comprehensive Impingement Monitoring Programme 2014-2017. Cefas, Lowestoft.

BEEMS Technical report TR406.v7. Sizewell C - Impingement predictions based upon specific cooling water system design. Cefas, Lowestoft.

Appendix A – Cefas sample summary from TR339

Table 4 Summary of sampling carried out during Cefas impingement sampling between April 2014 and October 2017. Each sample is designated by the sampling date, given as YYYY-MM-DD, where Day is the first day of the two-day sampling trip, the sampling duration (minutes) for each sample is given. The number of pumps in operation used to scale the data is provided. Following the Environment Agency Schedule 5 request a review of the original pumping capacity identified three occasions in 2016 (in red text) where the number of operational pumps was recorded as 3 (screens), when 4 pumps were operating (corrected in the table). For bulk samples, where the trash bin overflowed before the sampling was stopped, the sample was deemed as invalid and was not used in the raising calculations and the visit is highlighted in yellow. On four occasions (highlighted in blue), the first hourly sample could not be completed, due to issues with getting on-site permission to start work and on one occasion (highlighted in pink) sampling was abandoned after two hours due to severe weather conditions. All times GMT.

Sampling visit	Number of pumps	Sampling duration (minutes)						
		Hourly 1 09:00-10:00	Hourly 2 10:00-11:00	Hourly 3 11:00-12:00	Hourly 4 12:00-13:00	Hourly 5 13:00-14:00	Hourly 6 14:00-15:00	Bulk 15:00-09:00
2014								
2014-04-01	3		35	60	60	60	60	1100
2014-04-15	3	41	60	60	60	60	60	1096
2014-04-30	3	60	60	60	60	60	60	1080
2014-05-15	4	60	60	60	60	60	60	
2014-05-29	4	30	15	15	15	15	30	
2014-06-09	4	20	30	25	30	10	10	
2014-06-23	4	20	20	20	15	15	15	50
2014-07-02	4	15	15	15	20	10	15	
2014-07-16	4	30	20	30	20	20	20	
2014-07-30	4	60	60	60	60	60	60	
2014-08-12	4	60	60	60	60	60	60	
2014-08-27	4	45	30	30	30	30	30	
2014-09-03	4	35	23	60	60	60	60	1071
2015								
2015-04-28	3		45	60	60	60	60	1080
2015-05-06	4	60	60	60	60	60	60	1080
2015-05-14	4	60	60	60	60	60	60	
2015-05-28	4	60	60	60	60	60	60	
2015-06-15	4	30	60	60	60	60	60	
2015-06-25	4	30	10	10	10	15	15	
2015-07-02	4	14	15	15	15	15	15	
2015-07-15	4	20	20	15	20	20	20	
2015-07-28	4	23	30	45	40	15	15	
2015-08-03	4	25	40	50	38	20	35	
2015-08-18	4		60	60	60	60	60	1080
2015-09-08	4	60	60	60	60	60	60	1080
2015-09-29	4	60	60	60	60	60	60	1070
2015-10-08	4	60	60	60	60	60	60	1080
2015-10-15	4	50	45	60	45	45	45	
2015-10-29	4	45	60	60	60	60	60	1080
2015-11-03	4	60	60	60	60	60	60	1080
2015-11-18	3	60	45	30	45	60	60	
2015-12-01	3	45	30	30	30	60	60	

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Sampling visit	Number of pumps	Sampling duration (minutes)						
		Hourly 1 09:00-10:00	Hourly 2 10:00-11:00	Hourly 3 11:00-12:00	Hourly 4 12:00-13:00	Hourly 5 13:00-14:00	Hourly 6 14:00-15:00	Bulk 15:00-09:00
2015-12-15	3	45	60	60	60	60	60	
2016								
2016-01-07	3	60	60	45	30	30	20	
2016-01-19	3	15	30	45	40	60	60	
2016-02-01	3	35	30	30	60	60	60	
2016-02-11	3	60	60	60	60	60	60	
2016-02-23	3	60	60	60	60	30	45	
2016-03-03	3	60	60	60	60	60	60	
2016-03-14	3	60	60	20	30	35	15	790
2016-06-21	4	120	120	120	60	60	60	
2016-06-30	4	60	60	60	60	60	60	
2016-07-07	4	60	60	60	60	52	30	
2016-07-14	4	10	15	45	57	60	60	
2016-08-02	4	20	20	15	15	15	15	
2016-08-17	4	25	15	10	15	10	12	
2016-09-06	4	60	60	60	60	18	25	
2016-09-20	4	60	45	30	30	15	15	
2016-09-29	4	15	20	30	15	15	15	
2016-10-11	4	60	60	60	60	60	60	1080
2016-10-31	4	60	60	60	60	60	60	1080
2016-11-08	4	60	60	60	60	60	60	
2016-11-15	3	60	60	60	60	60	60	640
2016-11-24	3	25	20	20	20	20	30	
2016-12-07	3	60	55	45	45	45	40	
2016-12-19	3	60	45	45	55	60	60	
2017								
2017-01-10	3	15	15	30	30	30	30	
2017-01-18	3	45	45	30	30	45	40	
2017-01-26	3	30	30	20				
2017-02-07	3	25	50	30	15	15	30	
2017-02-23	3	90	80	45	30	30	30	
2017-03-06	3	60	60	60	60	45	45	840
2017-03-22	3	60	60	60	60	60	60	
2017-04-17	3	60	60	60	60	60	60	
2017-04-26	3		60	60	60	60	60	1080
2017-05-11	3	60	60	60	60	60	60	1070
2017-06-01	4	45	60	60	60	60	60	
2017-06-15	4	30	20	30	45	45	60	
2017-06-26	4	60	60	60	60	65	30	
2017-07-02	4	30	45	60	60	60	45	1070
2017-07-13	4	60	60	60	58	40	35	
2017-07-26	4	45	60	60	60	50	35	
2017-08-07	4	55	15	15	15	10	10	
2017-08-21	4	60	40	45	45	45	30	
2017-08-30	4	40	40	40	60	60	60	
2017-09-20	4	30	60	60	60	45	60	
2017-10-05	4	60	60	60	60	60	60	

Appendix B Mean, lower and upper numbers of fish estimated (SZB) and predicted SZC) to be impinged annually – full calculation tables

B.1 Calculated annual impingement by numbers at SZB and SZC without mitigation – all species

Annually raised and unmitigated number of individuals that are estimated to be impinged by SZB and predicted to be impinged by SZC, based on data from 2009-2017. Blue shading indicates the 24 key finfish species in the Greater Sizewell Bay. Numbers presented are based on errors in pumping raising factors and invalid bulk samples corrected and refinements to Sizewell B flow rates. Of the 91 described taxa in TR339.v3, 88 remain following the removal of invalid bulks.

Common name	Scientific name	SZB - estimate			SZC - prediction		
		Mean	Lower	Upper	Mean	Lower	Upper
Sprat	*Sprattus sprattus*	2,646,189	1,364,820	4,478,852	6,153,906	3,173,989	10,415,898
Herring	*Clupea harengus*	951,056	563,376	1,441,666	2,211,750	1,310,172	3,352,700
Whiting	*Merlangius merlangus*	642,935	471,160	840,402	1,495,192	1,095,717	1,954,416
European seabass	*Dicentrarchus labrax*	275,802	127,651	478,914	641,398	296,862	1,113,750
Sand gobies	*Pomatoschistus spp*	207,900	88,386	394,005	483,487	205,548	916,287
Dover sole	*Solea solea*	90,766	62,984	125,047	211,083	146,474	290,806
European anchovy	*Engraulis encrasicolus*	63,783	18,703	153,465	148,332	43,495	356,894
Dab	*Limanda limanda*	55,245	32,813	92,227	128,476	76,309	214,481
Thin-lipped grey mullet	*Liza ramada*	46,269	14,356	89,305	107,602	33,386	207,685
Transparent goby	*Aphia minuta*	39,095	16,391	81,560	90,917	38,118	189,673
Bib	*Trisopterus luscus*	31,227	14,551	53,021	72,620	33,838	123,305
Lesser weever fish	*Echiichthys (trachinus) vipera*	20,772	13,333	30,540	48,307	31,008	71,023
Nilsson's pipefish	*Syngnathus rostellatus*	13,995	2,530	28,822	32,547	5,883	67,028
Flounder	*Platichthys flesus*	13,824	10,478	18,151	32,149	24,367	42,211
Pogge (hooknose)	*Agonus cataphractus*	9,949	7,108	13,464	23,136	16,531	31,312
Cucumber smelt	*Osmerus eperlanus*	9,531	5,963	13,919	22,165	13,867	32,370
European plaice	*Pleuronectes platessa*	9,441	6,078	14,071	21,956	14,135	32,723
Five-bearded rockling	*Ciliata mustela*	8,754	5,436	13,593	20,359	12,642	31,610
Atlantic cod	*Gadus morhua*	7,097	2,458	13,247	16,505	5,716	30,807
Lesser spotted dogfish	*Scyliorhinus canicula*	5,149	2,524	8,879	11,973	5,871	20,648
Great pipefish	*Syngnathus acus*	4,524	2,093	7,323	10,522	4,868	17,031
Common sea snail	*Liparis liparis*	3,782	1,671	6,979	8,795	3,885	16,230

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Common name	Scientific name	SZB - estimate			SZC - prediction		
		Mean	Lower	Upper	Mean	Lower	Upper
Grey mullets	*Mugilidae*	3,722	0	16,165	8,655	0	37,594
Thornback ray	*Raja clavata*	2,881	1,794	4,228	6,700	4,172	9,833
Tub gurnard	*Trigla lucerna*	2,132	1,268	3,335	4,957	2,950	7,755
Unidentified herrings	*Clupeidae*	1,694	0	7,410	3,940	0	17,234
Pilchard	*Sardina pilchardus*	1,664	376	4,637	3,870	873	10,784
Starry smooth-hound	*Mustelus asterias*	1,563	729	2,581	3,634	1,694	6,003
Poor cod	*Trisopterus minutus*	1,441	300	3,099	3,352	697	7,208
Common dragonet	*Callionymus lyra*	1,438	626	2,669	3,345	1,457	6,207
Twaite shad	*Alosa fallax*	1,158	576	2,017	2,693	1,340	4,691
Black goby	*Gobius niger*	1,156	88	3,841	2,688	205	8,933
River lamprey	*Lampetra fluviatilis*	1,121	615	1,889	2,607	1,430	4,393
European eel	*Anguilla anguilla*	1,059	658	1,560	2,463	1,530	3,628
Three-spined stickleback	*Gasterosteus aculeatus*	1,015	256	2,928	2,360	594	6,809
Common sandeel	*Ammodytes tobianus*	940	384	1,927	2,185	892	4,481
Bullrout	*Myoxocephalus scorpius*	861	385	1,548	2,001	896	3,601
Scald fish	*Arnoglossus laterna*	781	392	1,293	1,816	912	3,006
Witch	*Glyptocephalus cynoglossus*	748	6	2,159	1,740	14	5,020
Great sandeel	*Hyperoplus lanceolatus*	692	222	1,338	1,609	515	3,111
Horse-mackerel	*Trachurus trachurus*	671	210	1,615	1,560	488	3,756
Brill	*Scophthalmus rhombus*	560	163	1,205	1,303	379	2,802
Rock goby	*Gobius paganellus*	476	11	2,008	1,106	26	4,670
Snake pipefish	*Entelurus aequoreus*	340	4	1,509	792	10	3,508
Lemon sole	*Microstomus kitt*	333	114	652	774	266	1,516
Solenette	*Buglossidium luteum*	282	81	601	656	188	1,398
Montague's seasnail	*Liparis montagui*	260	11	804	605	25	1,869
Sand Smelt	*Atherina boyeri*	169	6	420	394	14	978
Butter fish	*Pholis gunnellus*	148	47	285	344	110	664
Red mullet	*Mullus surmuletus*	134	38	286	312	88	666
Mackerel	*Scomber scombrus*	119	6	394	277	14	916
Tompot blenny	*Parablennius gattorugine*	113	16	306	263	36	712
Sandeels	*Ammodytidae*	95	0	296	220	0	688
Grey gurnard	*Eutrigla gurnardus*	94	15	232	220	35	538
Sea scorpion	*Taurulus bubalis*	87	8	213	203	18	496

SPP111 Sizewell C impingement predictions corrected for Sizewell B raising factors and cooling water flow rates

NOT PROTECTIVELY MARKED

Common name	Scientific name	SZB - estimate			SZC - prediction		
		Mean	Lower	Upper	Mean	Lower	Upper
Eelpout (Viviparous blenny)	*Zoarces viviparus*	87	0	247	203	0	575
Jeffrey's goby	*Buenia jeffreysii*	85	0	454	199	0	1,057
Garfish	*Belone belone*	76	10	182	177	24	423
Baillons wrasse	*Symphodus balloni*	76	0	236	176	0	549
Sand smelt	*Atherina presbyter*	64	0	266	148	0	618
Corkwing wrasse	*Crenilabrus melops*	59	0	186	137	0	434
Lesser forkbeard (tadpolefish)	*Raniceps raninus*	55	0	167	129	0	388
Frie's goby	*Lesueurigobius friesii*	55	0	168	128	0	391
Turbot	*Scophthalmus maximus*	49	3	134	114	8	311
Northern rockling	*Ciliata septentrionalis*	44	0	135	103	0	315
John dory	*Zeus faber*	33	0	91	76	0	211
Norway bullhead	*Micrenophrys lilljeborgii*	29	0	164	68	0	382
Sandeel	*Ammodytes marinus*	26	0	110	61	0	255
Tope	*Galeorhinus galeus*	24	0	89	55	0	207
Four-bearded rockling	*Enchelyopus cimbrius*	23	0	59	53	0	137
Ballan wrasse	*Labrus bergylta*	21	0	79	48	0	184
Spotted ray	*Raja montagui*	20	0	66	47	0	154
Lumpsucker	*Cyclopterus lumpus*	16	0	49	38	0	113
Crystal goby	*Crystallogobius linearis*	15	0	83	35	0	193
Thick-lipped grey mullet	*Crenimugil labrosus*	14	0	83	33	0	193
Black seabream	*Spondyliosoma cantharus*	9	0	38	21	0	89
Cuckoo wrasse	*Labrus mixtus*	8	0	46	19	0	106
Snake blenny	*Lumpenus lampretaeformis*	8	0	46	18	0	107
Goldsinny	*Ctenolabrus rupestris*	8	0	46	18	0	107
Pollack	*Pollachius pollachius*	7	0	39	15	0	92
Deep-snouted pipefish	*Syngnathus typhle*	5	0	28	11	0	65
Bigeye rockling	*Antonogadus macropthalmus*	4	0	16	10	0	37
Shore rockling	*Gaidropsarus mediterraneus*	4	0	19	9	0	44
Norway pout	*Trisopterus esmarkii*	4	0	23	9	0	55
Sea Trout	*Salmo trutta*	3	0	20	8	0	48
Red gurnard	*Aspitrigla cuculus*	3	0	15	6	0	35
Sea lamprey	*Petromyzon marinus*	2	0	11	4	0	26
Spotted dragonet	*Callionymus maculatus*	2	0	10	4	0	24

Common name	Scientific name	SZB - estimate			SZC - prediction		
		Mean	Lower	Upper	Mean	Lower	Upper
Allis shad	*Alosa alosa*	0	0	0	0	0	0
Saithe	*Pollachius virens*	0	0	0	0	0	0
Sand sole	*Pegusa lascaris*	0	0	0	0	0	0

B.2 Comparison between version 1 and version 2 of this report

Table 5. Annual unmitigated Sizewell C impingement estimate at full operational capacity. Raw impingement numbers are compared between version 1 and this report. Differences between version 1 and this report result from the removal of an additional 18 bulks samples between 2009 and 2013, when bulks are removed hourly samples are raised to estimate 24 hour impingement.

Common name	Sizewell C Corrected for pumps and bulk sample raising errors and refined flow rates – Version 1			Sizewell C Corrected for pumps and bulk sample raising errors and refined flow rates – Version 2			Difference in mean (% change)
	Mean	Lower	Upper	Mean	Lower	Upper	
Sprat	6,186,571	3,227,570	10,423,649	6,153,906	3,173,989	10,415,898	-0.5
Herring	2,240,583	1,363,711	3,348,502	2,211,750	1,310,172	3,352,700	-1.3
Whiting	1,491,448	1,072,817	1,988,567	1,495,192	1,095,717	1,954,416	0.3
European seabass	631,761	291,339	1,099,608	641,398	296,862	1,113,750	1.5
Sand goby	474,798	197,067	910,078	483,487	205,548	916,287	1.8
Dover sole	208,334	144,962	285,259	211,083	146,474	290,806	1.3
Anchovy	146,281	42,381	354,315	148,332	43,495	356,894	1.4
Dab	127,420	75,835	213,325	128,476	76,309	214,481	0.8
Thin-lipped grey mullet	109,307	33,637	210,313	107,602	33,386	207,685	-1.6
Flounder	31,893	23,870	42,160	32,149	24,367	42,211	0.8
Plaice	21,542	14,109	31,781	21,956	14,135	32,723	1.9
Smelt	20,446	13,105	29,300	22,165	13,867	32,370	8.4
Cod	16,853	5,863	31,363	16,505	5,716	30,807	-2.1
Thornback ray	6,744	4,193	9,926	6,700	4,172	9,833	-0.7
Eel	2,502	1,551	3,660	2,463	1,530	3,628	-1.6
Twaite shad	2,723	1,370	4,730	2,693	1,340	4,691	-1.1

SPP111 Sizewell C impingement predictions corrected for Sizewell B raising factors and cooling water flow rates

NOT PROTECTIVELY MARKED

Common name	Sizewell C Corrected for pumps and bulk sample raising errors and refined flow rates – Version 1			Sizewell C Corrected for pumps and bulk sample raising errors and refined flow rates – Version 2			Difference in mean (% change)
	Mean	Lower	Upper	Mean	Lower	Upper	
River lamprey	2,621	1,444	4,428	2,607	1,430	4,393	-0.5
Horse mackerel	1,584	500	3,793	1,560	488	3,756	-1.5
Mackerel	284	23	916	277	14	916	-2.5
Tope	55	0	207	55	0	207	0.0
Sea trout	8	0	48	8	0	48	0.0
Sea lamprey	5	0	26	4	0	24	0.0
Allis shad	0	0	0	0	0	0	0.0
Salmon							

B.3 Impingement estimates and predictions for key invertebrates

Table 6. Annual raw Sizewell B impingement estimates and Sizewell C predictions of key invertebrates at full operational capacity. Weight and number information is provided corrected for invalid bulk samples, data raising errors and application of flow rate refinement.

Common name	Year range	Sizewell B impingement estimate			Sizewell C impingement prediction		
		Mean	Lower	Upper	Mean	Lower	Upper
Weight (kg)							
Ctenophores	2009-2017	146,709	67,880	259,610	341,183	157,860	603,743
Common (brown) shrimp	2009-2017	8,567	6,034	12,121	19,923	14,033	28,188
Edible crab	2009-2017	562	348	796	1,306	810	1,852
Lobster	2009-2017	11	0	60	26	0	140
Number							
Ctenophores	2014-2017	62,048,986	26,115,332	112,069,242	144,299,458	60,733,117	260,625,225
Common (brown) shrimp	2009-2017	6,823,984	4,914,531	9,298,916	15,869,675	11,429,101	21,625,311
Edible crab	2009-2017	59,134	30,914	93,437	137,521	71,892	217,296
Lobster	2009-2017	28	0	112	65	0	260

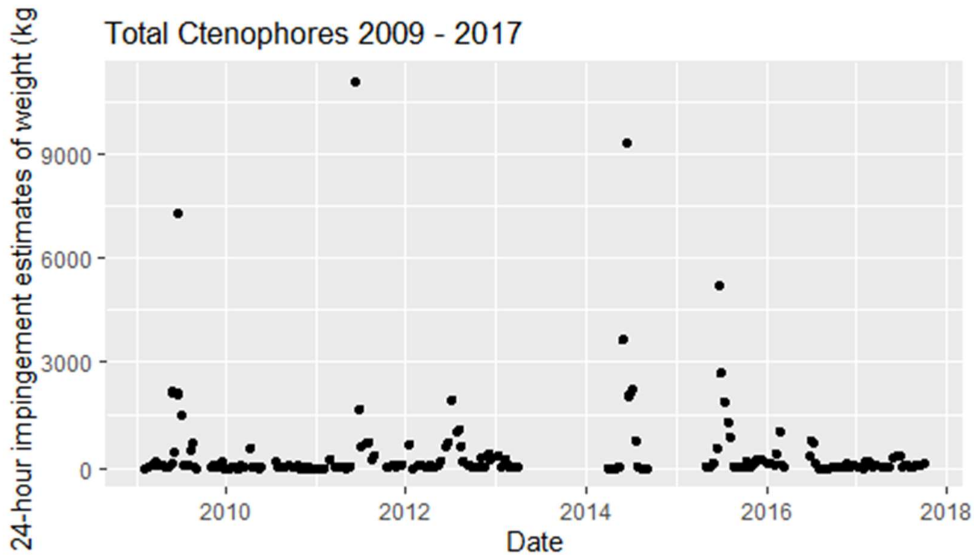

Figure 1 Estimated 24-hour impingement weight of ctenophores from impingement monitoring at Sizewell B between 2009-2017.