The Sizewell C Project

6.3 Volume 2 Main Development Site

Chapter 22 Marine Ecology and Fisheries

Appendix 22I - Sizewell C Impingement Predictions Based Upon Specific Cooling Water System Design

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Sizewell C – Impingement predictions based upon specific cooling water system design

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Please note that the red line boundary was amended after this document was finalised, therefore figures in this document do not reflect the boundaries in respect of which development consent has been sought in this application. However, amendments to the red line boundary does not have any impact on the findings set out in this document and all other information remains correct.

Executive summary

EDF Energy plans to build a new coastal nuclear power station (Sizewell C, SZC), adjacent to the operational Sizewell B (SZB) and decommissioned Sizewell A (SZA) sites in Suffolk. The station would be of a once-through design, abstracting large volumes of seawater for cooling the condenser steam. As part of the application for the building and operation of the new station, EDF Energy is required to evaluate the effects that the abstraction of seawater may have on the marine environment. The Centre for Environment, Fisheries and Aquaculture science (Cefas) supported by a network of subcontractors has been contracted by EDF Energy to undertake the necessary marine studies to provide the evidence base for the SZC DCO application via a comprehensive set of studies known collectively as the BEEMS programme for SZC.

SZC would need to abstract approximately 132 cumecs ($m^3 s^{-1}$) compared with approximately 51.5 cumecs for the existing SZB. SZB is the most recent nuclear power station to be constructed in the UK (commissioned in 1995) and is fitted with two measures to reduce the losses of impinged fish and crustacea; specially designed capped intake head and an early example of a Fish Recovery and Return (FRR) system. The cooling water intakes for SZC would be protected by widely spaced bars to prevent the intake of cetaceans, seals and large items of debris, but a significant number of small organisms (small fish and crustaceans, and plankton) will inevitably enter the cooling water intakes. The larger organisms must be removed before the water enters the power station cooling system to prevent them blocking the condenser tubes. These organisms are removed through impingement on rotating fine-mesh (10 mm at SZB, also proposed for SZC) drum screens which protect the main cooling water supply to the station condensers and band screens that protect the essential and auxiliary cooling water systems. The smaller organisms (mostly fish eggs and larvae and other plankton) that pass through the drum screens are entrained and pass through the power station cooling system without causing significant blockages.

Impinged organisms will be returned to the sea via a Fish Recovery and Return system (FRR). Not all will survive this process and separate assessments have been made to:

1. evaluate the impact of the loss of impinged organisms on fish populations (this report TR406)
2. evaluate the effect of any returned dead fish on local water and ecological quality. (BEEMS Technical Report TR520)
3. determine whether any beached fish would constitute a nuisance on local beaches. (BEEMS Technical Report TR511).

A separate report considers the significance of entrainment impacts on marine organisms (BEEMS Technical Report TR318) but the results are summarised in this report (TR406) to produce a combined entrapment assessment for SZC (Section 7.7).

Ninety-one finfish taxa were recorded at Sizewell over the 9-year study period. Of these 24 species have been selected as being representative of the fish assemblage and which include species of importance commercially, ecologically and from a conservation perspective. Similarly, four shellfish species were selected for assessment on the basis of commercial and ecological importance. Where possible impingement and entrapment predictions and compared against internationally coordinated stock assessments of agreed stock units for each species.

Selection of impingement mitigation technology for Sizewell C

The Environment Agency have issued guidelines for the types of measures that could be adopted at new direct cooled power stations to reduce the predicted environmental impacts of impingement and indirectly the potential for pollution by discharges of dead fish back into the marine environment (Environment Agency 2005, 2010). As explained in the Environment Agency guidelines, in practice the selection of potential impingement mitigation measures involves a complex consideration of the likely effectiveness of each measure in the marine environment at the station location, engineering feasibility and operational safety for staff and the plant. The range of options is much larger in freshwater and some brackish environments that do not present a high biofouling risk to station plant and for low volume abstractions (e.g. of a few cumecs) but many of these options are infeasible for a coastal direct cooled power stations (Environment Agency 2005). SZC's intakes would abstract 132 cumecs and would be mounted on the seabed in a highly turbid, coastal environment with high wave exposure offshore of the Sizewell-Dunwich Bank. The site is at high risk of biofouling.

A detailed consideration of the effectiveness and feasibility of the available impingement mitigation options has been conducted for Sizewell C and is summarised in Section 3. These studies demonstrated that two measures were both feasible and likely to reliably deliver reductions in the predicted losses of fish and crustacea:

i. Low velocity side entry (LVSE) intake heads
ii. Fish Recovery and Return (FRR) system with proposed 10mm mesh filtration and an anti-biofouling control policy that results in chlorination not being applied to the FRR system.

Both of these technologies are proposed SZC station and their use is predicted to reduce impingement mortality at SZC by the factors shown in Table 1 compared with an unmitigated SZC.

Table 1 Predicted reduction in impingement mortality for SZC fitted with LVSE intakes and FRR system compared with an unmitigated SZC.

Group	Example species	Impingement reduction at SZC
Pelagic fish	sprat, herring, anchovy, shads	62%
Demersal fish	bass, cod, whiting, grey mullet	77-79%
Epibenthic fish	eel, lampreys, sole, sand goby	92%
Shellfish	crab, lobster, brown shrimp	92%

Assessment of the significance of SZC impingement effects

There are no formal UK regulatory guidelines for assessing the significance of fish mortality levels caused by impingement in coastal power stations and therefore any assessment must be based on expert judgment.

For the purposes of this assessment we have adopted two screening thresholds that have been selected such that impingement losses lower than the appropriate threshold will have negligible effects on the year to year sustainability of a fish population. Effects above the appropriate threshold would not necessarily indicate a significant adverse effect but require further investigation to determine whether significant effects were, in fact, present.

The thresholds have been selected based upon internationally accepted scientific practice for the sustainability of fish stocks under anthropogenic pressures:

a. For commercially exploited stocks and conservation species (which includes stocks that are not currently exploited): 1% of the Spawning Stock Biomass (SSB) or, as a highly conservative proxy, 1% of international landings of the stock.
b. For unexploited stocks: 10% of the SSB or, as a highly conservative proxy, 10% of international landings of the stock.

The scientific rationale for the selection of these screening thresholds is detailed in Section 6.

For eel, twaite shad, allis shad, cucumber smelt and river lamprey a more precautionary approach was adopted of comparing SZC effects with 1% of a geographically limited subset of the entire stock. In particular, a highly precautionary approach was adopted for European eel whereby the Anglian River Basin District (RBD) SSB was used as the stock reference due the uncertainties surrounding both the current eel stock status and its stock dynamics (Sections 6.1.6, 7.6.4). This is equivalent to adopting a highly precautionary threshold of approximately 0.005% SSB for the eel stock.

Derivation of Spawning Stock Biomass estimates

Fish stocks in the Northeast Atlantic are managed partly through the EU Common Fisheries Policy (CFP), whose objective is to maintain or rebuild fish stocks to levels that can produce their maximum sustainable yield (MSY). The International Council for the Exploration of the Sea (ICES) advises public authorities with competence for marine management including the European Commission (EC).

ICES' advice is produced through a process which is set up to ensure that the advice is based on the best available science and data, is considered legitimate by both authorities and stakeholders and is relevant and operational in relation to the policy in question.

The basis for the advice is the compilation of relevant data and analysis by experts in the field, normally through an expert group which includes core researchers in the field. This analysis is peer reviewed by scientists who have not been involved in the expert group and have no direct interest in the matter.

To support the stock by stock management system, ICES provides advice on fishing opportunities and stock status for individual stocks including estimates of Spawning Stock Biomass (SSB). To undertake their stock assessments ICES' scientists have identified biological stock areas that describe the distribution of a stock. These may be different from the areas defined by the EU, for example, for the management of fishing quotas and technical measures. Identification of appropriate stock boundaries has been a central theme of ICES' coordinated effort since its formation in 1902 and major advances in understanding have, and continue to be, made.

Are ICES stock units appropriate for assessing the effects of SZC on fish populations?

The appropriateness of using some of the existing ICES stock units, particularly for bass which has one of the largest stock units of the key fish species included in the SZC effects assessment needs to be considered. In particular, whether the stock areas being used for the assessment of impacts to certain species consider the impact to local sub-populationsgiven numerous papers (including papers produced by ICES) provide evidence of sub-populations and more complex heterogeneous population structures.

Section 5.10.1 describes how ICES determines stock identity for fisheries management purposes, in particular how it uses evidence from ongoing research. The status of the bass stock unit and the direction of ongoing research is addressed and found not to alter the decision that ICES' current stock definition is scientifically the most appropriate. The section concludes that ICES' stock boundaries are compromises but they are based on a mature weighing of the best scientific evidence available and they are relied upon by governments to manage fish populations in the waters of all EU member states. Given the negligible predicted SZC impacts compared to those of fishing, and the precautionary nature of ICES' estimates of SSBs, no justification is found not to use the ICES' stock definitions to assess SZC effects on fish.

Assessment Results

Predictions of impingement have been provided for SZC without mitigation (Table 11), with mitigation that separately includes LVSE intake heads (Table 12) and FRR systems (Table 13) fitted and for the station fitted with both of the two mitigation technologies (

Table 15).

The individual entrainment and impingement impacts are such that when combined into a single entrapment estimate, there is very little difference to the overall conclusions that are reached when each is viewed separately. In the absence of impingement mitigation, species that exceed the 1 % threshold are bass, thin-lipped grey mullet, European eels and sand gobies. With the proposed impingement mitigation fitted entrapment estimates (Table 18) show the only species that remains above the 1 % threshold is sand goby (entrainment = 1.4 % of abundance; impingement = 0.0 %, i.e. entrapment = 1.4 %). Sand gobies are a short-lived very abundant species that is ubiquitous in European coastal areas to at least a depth of 20 m.

The species produces pelagic larvae which are dispersed by tidal currents resulting in a lack of genetic diversity over the southern North Sea. Given that the species is not commercially-exploited, the appropriate negligible effects threshold is 10% of SSB (as discussed in Section 6.1). However, because of their short lifespan and early age of maturity, sand gobies have a sustainable harvesting rate of greater than 50% SSB (Section 6.1.1). Therefore, losses of 1.4 % of total abundance by SZC are regarded as negligible.

Conclusions on the predicted effects of SZC entrapment

a. Of the 24 key fish and 4 key shellfish species, no species exceeded the 1% impingement screening threshold for negligible effects with the proposed LVSE intake heads and FRR systems fitted when compared against stock estimates or, in the absence of these, international landings. For the European eel, twaite shad, allis shad, cucumber smelt and river lamprey assessments a more precautionary approach was adopted of comparing SZC effects with 1% of a geographically limited subset of the entire stock. For eel this was equivalent to adopting a highly precautionary screening threshold of approximately 0.005% SSB. The predicted impingement effects of SZC on all of the key taxa were negligible (Table 2).

b. The predicted effects of SZC entrapment (i.e. impingement plus entrainment) with the proposed embedded impingement mitigation systems fitted were also negligible (Table 18).

c. An assessment of potential localised effects of SZC entrapment was undertaken (Section 7.8) and found no likely significant adverse effects on:
    i. spawning or nursery areas in the vicinity of Sizewell
    ii. the prey of HRA protected breeding little tern (the potentially most vulnerable species to localised effects on prey fish abundance at Sizewell).

Effect of SZC entrapment on the Water Framework Directive (WFD) assessment of local water bodies Section

Section 10 considers whether SZC entrapment has the potential to cause deterioration in the status of surface water bodies (both within and between status classes) by adversely affecting the fish biological quality element of two nearest transitional water bodies to Sizewell:

i. Blyth (S) at approximately 12 km to the north of Sizewell

ii. Alde & Ore at approximately 25 km to the south of Sizewell

The assessment concluded that SZC entrapment would have no significant effect on the calculated WFD fish biological quality element - the Transitional Fish Classification Index (TFCI). There would, therefore, be no predicted change in the WFD status of the Blyth (S) and Alde & Ore transitional water bodies due to SZC entrapment. This assessment included a specific consideration of the likelihood of any significant effects of SZC entrapment on smelt in the Alde Ore at the request of stakeholders. The conclusion of that study was that no significant effects are expected.

1.1 Revisions to impingement assessments

1.1.1 V2 report dated 9/12/2019

Since Version 1 of this report was released (03/06/2019), new details and clarifications on the proposed station design have emerged. Also, additional work has been undertaken to address issues raised by stakeholders. This has resulted in a number of revisions to this report both minor internal updates and more significant updates issued to stakeholders The major changes/impacts on the assessments that are included in this report are:

1. After a detailed modelling programme EDF Energy have decided to fit low velocity side entry (LVSE) intake heads at SZC. These intakes are designed to substantially reduce impingement impacts. Calculations have been undertaken to assess the effects of the proposed head design on SZC impingement and in conjunction with the proposed FRR mitigation.

2. The fine filtration mesh size is proposed to be 10 mm and the associated trash rack bar spacing proposed 75mm. No adjustments are therefore required for the mesh size as this is consistent with that of the current SZB station. A proposed wider trash rack spacing required an update to the proportion of each species that will either pass through or be retained on the trash racks. Trash rack mortality calculations have been updated accordingly.

3. Improved estimates of the populations of the conservation species; twaite shad, cucumber smelt and river lamprey have been included. This has substantially improved the confidence in impact assessment for these species. All tables have been updated accordingly.

4. Following stakeholder comments, estimates of the sand goby population have been updated. A calculation error was noted in the adjustment for beam trawl sampling efficiency. The population estimate has been re-scaled to the expected abundance if the trawl was fishing at 100 % efficiency.

5. Impingement estimates for key crustacea (brown crab, brown shrimp, lobster and whelks have been included in this version of the report.

6. All Appendices have been updated to the latest values. Following on from a stakeholder request, the final Appendix table for SZC (including all mitigation), now includes all calculation steps, including trash rack mortality.

7. An overall entrapment assessment has been included that presents the combined effects of impingement plus entrainment at SZC (Section 7.7).

1.1.2 V3 report dated 17/01/2020

1. Following the release of Version 2 of this report, an error was spotted with some of the stock data in that catch data (landings plus discards) were used, rather than landings only. This error affected four species only (whiting, cod, horse mackerel and dab). Assessments for the first 3 species were unaffected by the error as the primary stock comparator for these species is SSB and not landings. For dab, the result of replacing catches with landings was negligible – in the absence of mitigation, losses of dab changed from 0.01 % of catches to 0.04 % of landings. All calculations and tables for the four species have been updated.

2. Sections 5.7 on factors that could influence FRR mortality and 5.8 on EAV calculations have been expanded to provide clarifications in response to stakeholder comments. In particular, this report now provides:

    - An assessment of the potential for clogging of the FRR system by dead fish and ctenophores

- A critique of potential alternative methods of calculating EAVs

These were editorial changes only and they resulted in unchanged assessment results.

3. Following discussions with stakeholders at MTF meetings, further clarifications and explanations have been provided on the assessment of the predicted effects of SZC on:

    i. the endangered European eel stock in sections 6.1.6 and 7.6.4

    ii. the North Sea herring and the Blackwater herring in Section 7.6.5.

    iii. the local fish assemblage in Section 7.8.

4. A new Section 7.9 has been added to contextualise predicted SZC entrapment losses. The data included are an expanded version of those provided to stakeholders at the Sizewell MTF meeting on 18 December 2019.

1.1.3 V4 report dated 28/01/2020

1. Clarification of the development site red line boundary information added after the Table of Figures

1.1.4 V5 report dated 19/02/2020

In response to stakeholder comments clarifications have been added about:

1. The measured differences in bass abundance at the SZB and SZC intake locations; in particular how the surveys were intended to quantify previously well-established scientific facts about bass thermal preference in winter. Section 5.1.1.1.

2. Details of impinged eel length frequency distributions from SZB impingement data added in Section 7.6.4.3.

3. In response to Environment Agency comments dated 12 February 2012 on the v2 report. In particular, the following sections have been added:

    - Section 3 to summarise the extensive range of studies and the decision-making process that took place on the selection of impingement mitigation options to be fitted at SZC.

    - Section 5.10 which provides a justification of the use of SSBs derived from ICES's stock units to assess the effects of SZC on fish populations. A specific SZC question on the validity of the bass stock unit size is addressed in Section 5.10.2

    - Section 10 - Effect of SZC entrapment on the Water Framework Directive (WFD) status of local transitional water bodies. This assessment included a specific consideration of the likelihood of any significant effects of SZC entrapment on smelt in the Alde Ore (and potentially the Blyth) at the request of the Environment Agency.

1.1.5 V6 report dated 27/02/2020

1. Minor editorial correction to 5.1.1.1

    Table 9 updated with Sizewell C data to replace previous reference to Hinkley Point data.

Table 2 Annual mean SZC predictions of impingement for the 24 key species **with the proposed LVSE intake heads and FRR systems fitted and the corrections to bass and thin lipped grey mullet assessments incorporated as per Section 7.5**. Losses have been converted to adult equivalent (EAV) numbers and weights (t) and calculated as a percentage of the mean stock SSB (t) or, if this is not available, mean international landings (t). Species where the impingement weight > 1 % of the relevant stock comparator (given in bold) would be shaded red (there are none). Note, values in red font are estimates of the population numbers (e.g. sand goby) or reported catch numbers (salmon & sea trout)

Species	Mean SZC prediction (No mitigation)	SZC prediction with LVSE intakes	FRR mortality	EAV number	EAV weight (t)	mean SSB	% of SSB	Mean landings (t)	% of landings
Sprat	7,125,393	2,729,025	2,729,025	2,050,190	21.53	220,757	**0.01**	151,322	0.01
Herring	2,555,783	978,865	978,865	700,103	132.08	2,198,449	**0.01**	400,244	0.03
Whiting	1,865,492	714,484	393,295	140,044	40.03	151,881	**0.03**	17,570	0.23
Bass	57,537	22,037	12,133	2,717	4.16	14,897	**0.03**	3,051	0.14
Sand goby	381,612	146,157	30,108	30,108	0.06	205,882,353	**0.01**	NA	NA
Sole	250,059	95,773	19,729	4,200	0.90	43,770	**0.00**	12,800	0.01
Dab	148,921	57,037	30,715	13,656	0.56	NA	NA	6,135	**0.01**
Anchovy	73,865	28,290	28,290	27,558	0.57	NA	NA	1,625	**0.04**
Thin-lipped grey mullet	67,684	25,923	14,273	1,190	0.62	600	**0.10**	120	0.52
Flounder	38,180	14,623	3,377	1,559	0.13	NA	NA	2,309	**0.01**
Plaice	25,288	9,685	1,995	689	0.17	690,912	**0.00**	80,367	0.00
Smelt	23,863	9,139	9,139	6,959	0.12	105,733,825	**0.01**	8	1.36
Cod	16,845	6,451	3,884	1,395	3.63	103,025	**0.00**	34,701	0.01
Thornback ray	10,802	4,137	852	164	0.52	NA	NA	1,573	**0.03**
River lamprey	6,720	2,574	530	530	0.04	62	**0.07**	1	3.76
Eel	4,516	1,730	356	356	0.12	79	**0.15**	14	0.84
Twaite shad	3,601	1,379	1,379	1,379	0.43	7,519,986	**0.02**	1	32.40
Horse mackerel	4,077	1,561	1,561	1,561	0.22	NA	NA	20,798	**0.00**
Mackerel	628	241	241	241	0.08	3,888,854	**0.00**	1,026,828	0.00
Tope	64	24	5	5	0.03	NA	NA	498	**0.01**
Sea trout	10	4	4	4	0.01	NA	NA	39,795	**0.01**
Allis shad	5	2	2	2	0.00	27,397	**0.01**	0	0.68
Sea lamprey	5	2	0	0	0.00	NA	NA	NA	NA
Salmon	0	0	0	0	0.00	NA	NA	38,456	**0.00**

2 Background

EDF Energy plans to build a new coastal nuclear power station (Sizewell C, SZC), adjacent to the operational Sizewell B (SZB) and decommissioned Sizewell A (SZA) sites in Suffolk. The station will be of a once-through design, abstracting large volumes of seawater for cooling the condenser steam. As part of the application for the building and operation of the new station, EDF is required to evaluate the effects that the abstraction of water may have on organisms in the marine environment. Although the cooling water intakes will be protected by widely spaced bars to prevent the intake of cetaceans, seals and large items of debris, a significant number of small organisms (small fish and crustaceans, and plankton) will inevitably enter the cooling water intake. The larger organisms must be removed before the water enters the power station cooling system to prevent them blocking the condenser tubes. These organisms are removed through impingement on rotating fine-mesh (10 mm at SZB, also proposed for SZC) drum screens which protect the main cooling water supply to the station condensers and band screens that protect the essential and auxiliary cooling water systems. The smaller organisms (mostly fish eggs and larvae and other plankton) that pass through the drum screens are entrained and pass through the power station cooling system without causing significant blockages. Impinged organisms will be returned to the sea via a Fish Recovery and Return (FRR) system. Not all will survive this process and EDF Energy is required to evaluate the effect of the loss of these organisms on marine communities and also of the potentially polluting effects of dead biota discharged from the FRR system on local water quality and marine ecology.

As was the case for Hinkley Point C (HPC), the impingement assessment process for SZC makes use of extensive impingement data collected at the adjacent power station. However substantial differences between the two existing power stations have created very different assessment datasets and necessitated a more complex statistical modelling based approach for the SZC assessments (Section 5). At HPC, assessment of impingement losses was made using data collected at the Hinkley Point B (HPB) station (BEEMS Technical Report TR456). The assessment used data collected in 2009 – 2010 from a sampling programme, known as the Cefas Comprehensive Impingement Monitoring Programme (CIMP), which comprised 40 * 24-h samples to estimate annual impingement of the station. The predictions were supported using information from the lower-resolution Routine Impingement Sampling Programme, which has sampled for over 35 years at the HPB site, but at a lower sampling effort.

Prior to the BEEMS programme, there was no regular impingement sampling at the SZB site. To fill this data gap, a CIMP programme was initiated in 2009 to provide the necessary data for predictions of impingement for the proposed SZC site. The CIMP was designed to provide 24-h sampling of the fish, invertebrates and other material passing through the SZB cooling water systems on 28 to 40 occasions per year. Between February 2009 and March 2013, 128 sampling visits were completed. Following a break in sampling, a further 77 visits were completed between April 2014 and December 2017, giving rise to a dataset comprising 205 samples. A description of the sampling undertaken between 2009 and 2013 can be found in BEEMS Technical Reports TR120, TR196, TR215, and TR270, and details of the 2014 – 2017 sampling can be found in BEEMS Technical Report TR339. The dataset was used to provide an annual estimate of the numbers and weights of fish and invertebrates impinged at the SZC station for the 9-year period. A total of 91 finfish and 62 invertebrate taxa were recorded.

2.1 Selection of key taxa for SZC impingement assessment

The impingement assessment process for SZC is described in Section 5.

For the purposes of the Sizewell marine ecology impact assessments, taxa are key in the ecosystem if they meet at least one of the following criteria:

- Socio-economic value: Species that contribute to the first 95 % of the first sale value of commercially -landed finfish in the area off the east Anglian coast and contributes to the first 95 % of total abundance in at least one of the available datasets (2 m beam trawl, otter trawl, BEEMS eel survey, annual impingement). Commercial landings are recorded using statistical rectangles that divide the southern North Sea into areas of 30 minutes latitude by 1 degree longitude and covering approximately 900 nautical miles^2. For the purposes of describing local commercial fisheries, 6 rectangles have been considered, that extend from north Norfolk to the Thames estuary and eastwards to the middle of the North Sea (BEEMS Technical Report TR123). Socio-economic value was calculated using data supplied by the Marine Management Organisation (MMO) and which was used in BEEMS Technical Report TR123. 6 taxa (**Herring, bass, sole, cod, plaice, thornback ray**).

- Conservation importance: The "S41 Priority Species" spreadsheet given by Natural England (http://publications.naturalengland.org.uk/publication/4958719460769792) was used to assess the conservation status of the fishes recorded in the Greater Sizewell Bay. This spreadsheet was built based on the legislation in Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006. It is worth noting that measures in place to provide protection for the named species apply to the adult stock rather than the eggs or larvae, and focus on halting the decline of the spawning stock biomass mainly via restriction on exploiting recruited species. The resulting list contains one species which has not been detected in the extensive BEEMS sampling programmes (Atlantic salmon). 16 taxa (**allis shad, twaite shad, European eel, herring, Atlantic cod, whiting, plaice, sole, salmon, sea trout, cucumber smelt, river lamprey, sea lamprey, tope, mackerel, horse mackerel).**
- Ecological importance: If a taxon is present in at least 30 % of samples and contributes to the first 95 % of total abundance in at least one of the available datasets (2 m beam trawl, otter trawl, eel surveys, annual impingement), we consider it to be common and/or abundant enough to play a key trophic role within the ecosystem. 13 taxa (**sprat, herring, whiting, bass, sand goby, sole, dab, anchovy, thin lipped grey mullet, flounder, cod, plaice, thornback ray)**.

There are 24 key fish taxa in the Greater Sizewell Bay in total based on either their commercial value, their ecological importance, or their conservation status. Several taxa fall under more than one criterion and four taxa are important with respect to all three (Dover sole, herring, cod and plaice) (BEEMS Technical Report TR345).

The 24 species are representative of the fish assemblage at Sizewell because:

a. they represent an average of 94.6% of the total fish impingement numbers during the CIMP programme from 2009-2013;

c. they contain examples from all functional guilds with the exception of freshwater species which, as would be expected, are rarely found at Sizewell;

d. they contain examples from all the feeding guilds and habitat groups;

e. they contain all of the indicator species found in the vicinity of Sizewell that are assessed in the WFD “fish” biological quality element in transitional waters; and

f. they contain the key prey species that supports the food web at Sizewell (including for HRA protected marine birds.

2.1.1 Conservation species impingement data

In the 9 years of extensive impingement sampling, catches of 4 conservation species were extremely rare or non-existent:

Atlantic salmon	0 fish
Allis shad	1 fish in 2009
Sea lamprey	1 fish in 2015

- Sea trout 1 fish in 2010

None of these species were caught in any of the BEEMS fishing surveys. Salmon is, therefore, not expected to be impinged at SZC.

The lone Allis shad is considered to be a straggler from the Garonne population (BEEMS Scientific Position Paper SPP071/s) because this is the largest self-sustaining population that is closest to Sizewell. (There is no evidence that the Allis shad found in the Tamar are part of a self-sustaining population). Making no allowances for the fact that only one fish was caught, the predicted unmitigated impingement at SZC is five fish per annum, which decreases to only two fish per annum with the effect of the intake head design. It is not statistically valid to extrapolate this data point to future years and a more meaningful assessment would be to compare the scaled-up impingement in 2009 with the stock estimate for that year of 27,397 adults (BEEMS Technical Report TR456). This is the stock comparator that has been used in this report.

The predicted impingement for sea lamprey is also five fish but with the effect of the LVSE intake head design, this drops to only two fish impinged. Actual impingement losses considering survival through the fitted FRR mitigation are < 1 fish per annum (again using a statistically invalid extrapolation technique from the one fish caught in the CIMP programme). Allowing for the fact that only one fish was caught in the eight years when sampling took place, the predicted impingement is <0.13 fish per annum which is ecologically insignificant. No attempt has been made to put such a negligible impact into an adult stock context as the effect is insignificant.

The lone sea trout caught in the CIMP programme is considered to be from the UK North East coast population. A highly conservative assessment has been made in this report for sea trout based upon scaling up the 1 sea trout caught in May 2010 to a model output of 10 fish per annum for SZC without impingement mitigation. After adjustment for the impingement reduction by the LVSE intakes, the annual impingement loss estimate for SZC is approximately 4 fish per annum (Table 2). This estimate has then been compared with the annual mean net catch for sea trout in the sampling period to produce an estimated SZC effect of 0.01% of annual landings. The use of landings statistics overestimates the effect on the stock as landings are much less than the SSB. However, this simplistic assessment is not appropriate for such rare impingement events as it does not take into account that no other sea trout were detected in the period 2009 -2017. Allowing for the fact that only one fish was caught in the eight years when sampling took place, the predicted SZC impingement is approximately 0.5 fish per annum which is ecologically insignificant.

2.2 Aims of this report

The purpose of this report is to provide predictions of SZC impingement, based on the CIMP dataset collected between 2009 and 2017.

Aims:

- Provide predictions for all key finfish and shellfish species, based on the proposed design of the station with and without the selected impingement mitigation technology fitted.
- Place the predicted losses of these key species into the context of the most relevant stock unit area.
- Determine whether SZC impingement represents a significant effect for any of the key species
- Determine whether SZC entrapment (impingement predictions from this report +entrainment predictions from BEEMS Technical Report TR318) represents a significant effect for any of the key species
- The impingement predictions from this report are used to provide the source term for modelling the impacts of dead fish discharged from the SZC FRR system upon the local marine environment.

3 Selection of impingement mitigation measures for SZC

The Environment Agency have issued guidelines for the types of measures that could be adopted at new direct cooled power stations to reduce the predicted environmental impacts of impingement and indirectly the potential for pollution by discharges of dead fish back into the marine environment (Environment Agency 2005,2010). As explained in these guidelines, in practice the selection of potential impingement mitigation measures involves a complex consideration of the likely effectiveness of each measure in the marine environment at the station location, engineering feasibility and operational safety for staff and the plant. The range of feasible mitigation options is much larger in a freshwater and some brackish environments that do not present a high biofouling risk to station plant and for small abstractions of a few cumecs but many of these options are infeasible for a coastal direct cooled power stations (Environment Agency 2005). SZC's intakes would require an abstraction of 132 cumecs and would be mounted on the seabed in a highly turbid, coastal environment with high wave exposure offshore of the Sizewell-Dunwich Bank. The site is classified as being at high risk of biofouling.

3.1 Biofouling and other blockage risks

Design decisions on the choice of impingement mitigation options have to be taken in light of the environmental risks to the plant from the Sizewell marine environment. The cooling water system for SZC would be nuclear safety classified and it is therefore extremely important that the system is designed to prevent blockages of critical plant. The blockage hazards at Sizewell include:

- marine debris (discarded nets and ropes and marine litter – this risk also includes potential impact damage from large and heavy items) and large clogging organisms (e.g. in the southern North Sea: sprat shoals and ctenophore blooms)
- colonisation by biota (biofouling) that could cause blockages and subsequent reductions in cooling water flow in the system (e.g. shellfish, barnacles, reef forming organisms)
- siltation due to high suspended sediments (risks designed out by elimination of low velocity regions in high risk zones of the cooling water system e.g. intake heads and forebays

Established power station design practice is to progressively reduce the risks from marine debris and large clogging organisms by the use of robust, coarsely spaced intake bars at the intakes followed by two tiers of filtration within the plant (trash racks and then drum or band screens). Colonising organisms are deterred by chlorination of the cooling water system (Note chlorination is designed to deter settlement rather than to kill organisms).

EDF Energy's policy for its existing UK fleet is that stations exposed to a high biofouling risk should have the capability of maintaining a default regime of continuous, year-round chlorination to obtain 0.2 mg l^{-1} Total Residual Oxidant (TRO) in the discharge water from plant vulnerable to biofouling. Sizewell B is currently assessed as subject to a high risk of biofouling and operational practice is, therefore, to maintain the default regime. The detailed application of the EDF Energy policy, for example whether the entire cooling water (CW) system is dosed continuously or just critical plant, is dependent upon site specific issues such as the flexibility of the chlorination plant. At SZB the current policy is to dose the entire CW system, including the inlet tunnels, throughout the year.

Based upon the known risk of biofouling at Sizewell, it would be necessary to dose critical plant at Sizewell C (the condensers and essential cooling water systems) during the growing season when seawater temperatures exceed 10 °C and also to have the flexibility to dose those systems at other times of the year based upon operational need. The chlorination policy for the other parts of the CW system has to be effective against any biofouling risk that would threaten the operation of the station whilst minimising toxicological effects on non-target species. In particular, Sizewell C will be fitted with a Fish Recovery and

Return (FRR) system (Section 3.4.1) to reduce the mortality of impinged fish. The Environment Agency best practice screening guidelines are that, wherever possible, chlorination should be avoided before the FRR so as to minimise any loss of fitness for those fish returned to the marine environment. This is a larger environmental issue for Sizewell C (SZC) than Sizewell B (SZB) due to the length of the SZC CW tunnels and the potential significant increase in TRO exposure time, dependent upon chlorination system design, for organisms abstracted into the CW system.

3.2 Impingement Mitigation Optioneering

EDF Energy have carefully considered each of the available options in the Environment Agency guidelines. The initial stage is to determine the location of the intake and outfall locations at a site based upon environmental and engineering considerations. In practice given practical engineering constraints on intake siting and intake tunnel length, the available options may not significantly change the predicted abstraction of organisms in a well-mixed environment. For most species this is the case at Sizewell (Section 5.1.1). There are measures to reduce the mortality of impinged fish and crustacea but for planktonic organisms (e.g. zooplankton, fish eggs and fish larvae) due to their small size (typically less than a few mm in length or diameter) little can be done to reduce the numbers and mortality of entrained organisms. However, due their number, spatially ubiquitous nature and the high natural mortality of the majority of planktonic organisms, entrainment impacts from coastal power stations are rarely significant and that is the case predicted for SZC (Section 7.7). There are two complementary mitigation technological approaches to minimise impingement losses using:

a. Biota exclusion technology - measures to minimise the number of organisms abstracted into the station intakes; and

b. Biota recovery technology - measures taken inside the cooling water system to filter organisms out of the cooling water stream and safely return as many as possible of them alive to sea.

3.3 Biota exclusion technology

Several techniques are available, with variable effectiveness, to reduce the number of fish and crustacea being abstracted with the seawater and impinged on the cooling water fine filtration systems (drum or band screens). These measures are located at or close to the intakes which for SZC would be in the open sea at more than 3km offshore to the east of the Sizewell-Dunwich sandbank and mounted on the seabed. From a design perspective the five key requirements of such technology for SZC are:

- Compatible with nuclear safety requirements for an uninterrupted supply of cooling water for the 60-year operational life of the station. This implies the use of systems that are highly resistant to damage or blockage and that are readily maintainable in all weather conditions, all year round.
- Operation and maintenance compatible with the EDF Energy’s zero harm safety policy for staff and contractors. i.e. no requirement for activities judged hazardous to human life.
- Proven operational experience in a similar environment that demonstrates reliable delivery of effective environmental mitigation.
- Due to the offshore environment any system should preferably use entirely passive technology e.g. requiring no power, chemical supplies or compressed air systems that could compromise reliability and hence nuclear safety and environmental effectiveness.
- System operational maintenance requirements must be compatible with high power plant availability.

The potential biota exclusion techniques include:

i. Physical barriers (e.g. wedge-wire screens and bubble curtains);

ii. Auditory or visual behavioural deterrents that aim to deter fish from a trajectory likely to cause their abstraction (e.g. acoustic fish deterrents (AFDs) and strobe lights; respectively).

iii. Design of the intake heads to minimise the risk of biota abstraction e.g. by use of velocity-capped intake heads, limiting intake velocities, minimising abstraction cross sectional area by mounting the intake orthogonal to the tidal flow. Low velocity side entry (LVSE) intake heads combine all of these attributes and represent the state of the art for such an approach and are included in the approved design for HPC.

Several of these measures have been deployed in riverine locations. However, for existing coastal power stations only limited intake head design improvements (e.g. use of velocity caps, and sizing intakes to reduce intake velocities) or more recently AFDs have been deployed. AFDs have only been deployed at stations with onshore or very nearshore intake locations and none have been deployed at far offshore locations (e.g. the 3km+ offshore locations proposed for SZC).

Each of the biota exclusion options are considered in turn below.

3.3.1 Passive wedge-wire cylinder screens (PWWC screens)

In principle, the best form of impingement mitigation could be to prevent abstraction of fish and crustacea by the use of very fine screens with gaps of a few millimetres. Environment Agency (2005) considers that “Passive wedge-wire cylinder (PWWC) screens are a tried and tested solution and are generally regarded in Britain as the best available technology for juvenile and larval fish protection”. Wedge-wire’ refers to the cross section of the welded wires that are wound helically to form a cylindrical screen surface.

PWWC screens are commonly used to exclude fish from small, riverine abstraction intakes and there are also some small industrial applications in brackish and saline waters. However, because of the very small gaps between the wires the screens are at high risk of becoming blocked or damaged by floating debris, weed and litter even in riverine environments. In the marine environment the risks are much greater due to the potential hazards from ctenophore blooms, pelagic fish shoals and marine debris and also particularly from biofouling by colonising organisms. To reduce the blockage risk in high risk environments, PWWC systems have complex maintenance requirements with frequent, active cleaning required (for example with rotating mechanical brushes or by the injection or high-pressure air). The maintenance advantage of the passive screen then largely disappears as the active cleaning systems present significant reliability risks. Practical PWWC systems are complex systems, that must be recovered for regular maintenance including to repair damage to the fine screens. To do this such filters are usually track mounted on large motorised platforms attached to the shore.

It is instructive to consider the theoretical sizing of a PWWC system for SZC. The abstraction capacity of PWWC filters depends upon the wire spacing. To eliminate most impingement issues (and to comply with the Environment Agency screening guidelines for glass eels) it would be necessary to employ a 2 mm wedge wire filter. The largest commercially available 2 mm PWWC filters would permit an abstraction of 2.7 cumecs with an 8m long, 2.5m diameter cylindrical filter i.e. to create the required 4 intake head system for SZC with a total abstraction of 132 cumecs would need a minimum of 13 PWWC filters per head, probably15+ allowing for redundancy for cleaning and repair. i.e. a total of up to 60+ filters for SZC with each head length being greater than 130m in length, all track mounted on 4 powered offshore platforms complete with compressed air cleaning and antibiofouling chemical supply. The lifetime for such complex systems are unknown but certainly are not the required 60 years for SZC. The required recovery frequency for the filters is also unknown but in the growing season could be monthly. The filters would require frequent replacement using heavy lifting equipment and the track mounting would also require replacement, probably on at least a decadal frequency. No such system has been deployed at any power station worldwide.

Conclusion: PWWC filtration is an unproven technology for direct cooled nuclear power stations and is not considered compatible with nuclear safety requirements for a constant supply of cooling water.

This is the only potential technology that could theoretically eliminate impingement and therefore any other mitigation measure would require technology to recover organisms from the station drum and band screen.

3.3.2 Bubble curtains

The use of a bubble curtain, whereby air is released along a section of seabed to create a ‘curtain’ of bubbles rising to the surface and thus creating a barrier to fish, is a potentially useful exclusion technique in still or slow-moving waters but is not suitable as a permanent exclusion system for waters where tidal currents ebb and flow at >1m/s and would break down the curtain of bubbles. Small sized bubble barrier systems to reduce underwater noise have been temporarily deployed at sea from jack up rigs during periods of low tidal velocities during windfarm piling activities but never around the required large intake heads of a power station at all states of the tide and in all weather conditions.

Conclusion: bubble curtains are an unproven technology for use around the offshore intakes of direct cooled nuclear power stations and are considered unlikely to deliver substantial impingement mitigation at Sizewell.

3.3.3 Behavioural deterrents – strobe lights

Strobe lighting, can be used to deter some fish (for example eels), however, their effectiveness in turbid coastal waters is unproven (turbidity relates to the amount of material; suspected in the water and thus restricting visibility). The surface water at Sizewell is classified as “intermediate turbidity” and experiences increased levels of turbidity in autumn to spring when storms and increased wave action stirs up sediment. Repeated surveys have demonstrated that it is extremely difficult to photograph any seabed features at Sizewell due to this limited visibility. The near-bed conditions at the Sizewell C intake locations have particularly high levels of suspended sediment with measured levels of greater than 2 g/l at the height of the proposed intake surfaces due to sediment transport around the Sizewell-Dunwich Bank and mean winter values of ca. 500 mg/l (BEEMS Technical Report TR498). Such high levels of suspended sediments dramatically reduce the penetration of light through the water and would prevent strobe lighting from having an effective deterrent function.

Conclusion: strobe lighting is an unproven technology for use around the offshore intakes of direct cooled nuclear power stations and is considered unlikely to deliver impingement reductions at Sizewell.

3.3.4 Behavioural deterrents - electric barriers

An electric fish barrier is a non-physical barrier that prevents fish passage from one location to another or induces fish movement from one area to another within a body of water using an electric current. Electric barriers pass an electrical current through the water, thus creating an electric field. As fish enter the electric field they become part of the electrical circuit and experience electric current flowing through their body. As the fish approaches the anode, the electric field intensifies, which causes the fish to generally turn around and swim away from the electric barrier. The set-up of an electric barrier requires a series of electrodes, alternating anodes and cathodes to span across a body of water. However, electric barriers are affected by water conductivity and are unsuitable for marine or brackish water environments, therefore, the use of an electric fish barrier is not feasible for the offshore Sizewell C intakes.

Conclusion: Not feasible

3.3.5 Behavioural deterrents - Acoustic fish deterrents (AFDs)

Well-designed AFD systems have been reported to reduce impingement of some fish species by creating high intensity sound fields of swept frequency pulses of sound around an intake thereby causing some fish to change direction and move away from the sound field. The available commercial systems are predicted to work well with sensitive pelagic species (e.g. sprat and herring), moderately for a range of demersal species (e.g. cod, whiting) and poorly for species with either low hearing ability or low responsiveness to the underwater frequencies used such as eels, lampreys, and some flatfish. All power station installations of AFDs are either on shore or very close to shore to facilitate system maintenance. There are no AFD systems operating in environments at multiple kilometres offshore as they would have to be at SZC.

An AFD system for SZC would necessarily be very similar to that evaluated for HPC and would require up to 288 underwater sound projectors located at the CW intakes approximately 3km offshore. The issue of system longevity is a particular constraint as the AFD sound projectors need to be recovered and serviced on shore currently at 12 monthly intervals, possibly at up to 18-month intervals with further research. Other key issues with installation of AFDs in offshore environments are the large number of electrical components required at each intake, the supply of reliable high levels of electrical power and control telemetry to the individual sound projectors and the required close proximity of the projectors to the intake heads themselves (without affecting the hydrodynamic performance or structural integrity of the head. The recovery of the projectors for maintenance would be a major issue. Four permanent offshore platforms with track mounted projectors could theoretically be used but the these would have to be very close to the intakes, affecting the hydrodynamic performance of the intake heads and the resultant sound field would be likely to have an unpredictable deterrent effect due to complex interference patterns caused by the structures themselves. More significantly, such a complex track mounted system with a profusion of electrical wiring would also have major issues with long term reliability for the 60-year lifetime of the station in the corrosive marine environment at the site. The use of such structures is not considered feasible. In the near zero underwater visibility at the SZC intakes the use of robotic servicing via remotely operated vehicles is not considered feasible and instead each of the projectors would have to be recovered and replaced using divers working by feel, operating from anchored support vessels for months during every year, for the 60-year lifetime of the station. The system would be extremely complex to construct and to maintain with offshore operations restricted to narrow tidal windows and subject to lengthy periods of weather downtime in the exposed location offshore of the Sizewell-Dunwich Bank. An assessment of the risks involved with such an operational system has concluded that the safety risks to maintenance staff would be unacceptable.

Conclusion: Logistical and safety considerations preclude the use of AFDs at Sizewell C.

3.3.6 Intake design - LVSE intakes

Low velocity side entry (LVSE) intake heads have already been designed and received regulatory approval for use at HPC. These very large intake structures are designed to minimise impingement by:

a. reducing vertical velocities which fish are ill equipped to resist by means of velocity caps on the intakes.

b. limiting the exposure of the intake surfaces to the tidal stream and in so doing reduce the risk of impingement for fish swimming with the tidal stream. i.e. to reduce the cross-sectional area of the intake to the prevailing tidal directions by mounting the head orthogonally to the tidal flow.

c. reducing intake velocities into the head to a target velocity of 0.3m/s over as much of the length of the intake surface which will maximise the possibility of most fish avoiding abstraction

LVSE intakes have the advantage of reducing impingement for all fish species at risk of abstraction. The HPC LVSE intakes will be the first deployment of this technology on an operational power station worldwide and represent a considerable advance in the design of intake heads. One option for SZC would have been to reuse the HPC design. However, Hinkley Point has a low biofouling risk whereas Sizewell has a high risk and the starting point for SZC would be an assumption of chlorinating the entire cooling water system starting at the intake heads. Studies demonstrated that the required chlorine dose combined with the exposure time in the 3km tunnels would significantly reduce the survival of many of the species that the FRR is designed to protect. After a consideration of risk and engineering feasibility by EDF Energy, based upon operational experience at Sizewell, the size of the proposed SZC intake tunnels and the use of a simple SZB style capped intake for SZC it was decided that it would be acceptable not to chlorinate the intakes and intake tunnels, thereby significantly reducing the exposure of abstracted organisms to TROs. This led to the initial recommended chlorination policy for SZC described in BEEMS Technical Report TR316:

a. Maintaining a TRO level of 0.2mg l^{-1} at the discharge of critical land-based plant (condensers and essential cooling water systems) throughout the year.

b. Intake heads, inlet tunnels and the forebays not to be chlorinated because of the impracticality of operational control of the chlorination dose in the intakes and inlet tunnels and so as not to compromise the FRR system effectiveness.

c. Velocity-capped intake heads of a similar design to Sizewell B to be employed at Sizewell C. Such intake heads are much more readily maintained and much less likely to biofoul than the low velocity side entry (LVSE) intake heads planned for Hinkley Point C.

d. In order to protect the drum screens and FRR system, chlorinate the drum screen wells but only in the growing season when seawater temperatures exceed 10 °C.

e. Apply for a WDA discharge permit for TRO (measured before the discharge tunnel) of 0.2mg l^{-1} throughout the year.

Further studies demonstrated that even this revised chlorination policy would impair the effectiveness of the FRR system for demersal species such as the juvenile bass found at Sizewell. After a further careful engineering review the first dosing point in the cooling water system was moved to after the drum screens thereby removing chlorination from the FRR system.

The decision to use SZB style omnidirectional velocity-capped intakes was based upon a risk assessment that concluded that the unchlorinated LVSE intake heads designed for HPC would present an unacceptable biofouling risk at Sizewell due to the surface area of the baffles inside the intake head structure. If the HPC LVSE heads were fitted at SZC the entire CW system would have to be chlorinated, effectively eliminating the benefit of the FRR system for most species. However, the SZB style velocity-capped intake heads would offer no impingement rate improvement over the existing SZB intakes; in particular organisms swimming in the tidal stream would still experience high intake velocities in excess of 1m/s for a large part of the tidal cycle which would be too high to permit most organisms to avoid abstraction.

To reduce the biofouling risk, it was necessary to remove as many of the internal baffles in the HPC LVSE intake design as possible and to reduce areas of low velocity flow within the head. After extensive computational fluid dynamics (CFD) modelling studies of a range of LVSE designs it was determined that a modified version of the HPC LVSE intake heads could be designed to have low biofouling risk and achieve the same reduction in cross sectional area as the HPC intake heads. By improving flow dynamics within and around the heads the modified heads the variation in intake velocities across the intake surfaces could also be minimised and permit low intake velocities to be achieved over the whole tidal cycle (Section 7.8.3, BEEMS Scientific Position Paper SPP099).

Conclusion: LVSE intakes, modified from the HPC design to reduce biofouling risk would provide reliable and effective impingement reduction for SZC.

3.4 Biota Recovery Technology

3.4.1 Fish Recovery and Return System

A Fish Recovery and Return (FRR) system is designed to return robust species (particularly flatfish, eels, lampreys and crustacea and to a lesser extent demersal species such as bass, cod and whiting) that are impinged onto the station drum and band screens safely back to sea. A state of the art fish recovery return system has been designed and received regulatory approval for Hinkley Point C. This system has been subject to intensive design scrutiny and complies with Environment Agency guidelines for such systems. EDF Energy policy for SZC is to replicate the design of HPC as far as possible and so it has been decided to incorporate the HPC design into SZC. The tidal range at Sizewell is less than at Hinkley Point and it has, therefore, been possible to improve the fish friendliness of the SZC FRR system by removing an Archimedes screw system that is essential to manage water levels in the HPC cooling water system.

The drum and band screen employ fine mesh filters to remove impinged organisms from the cooling water flow. The default mesh size for the EPR reactor is 5 mm square as opposed to the 10 mm mesh filters employed at SZB. After careful consideration of the risk of clogging by summer ctenophore blooms at Sizewell, it has been proposed to fit 10 mm mesh filtration for SZC which has been operationally proven not to cause clogging at SZB. Trash racks are used to protect the drum and band screens from damage and over loading. With a 5 mm mesh the track rack has to have 50 mm vertical bar spacing, a 10 mm mesh size could allow the trash rack bar spacing to be increased to 75 mm. The environmental effects of the larger track rack bar spacing and the larger mesh size are beneficial and will reduce the predicted effects on fish stocks. The larger mesh size will also reduce discharges of dead biomass from the FRR outfall. There would be no adverse effect on the survival of any glass eel that may be abstracted as glass eels would pass through both 5mm or 10mm filtration.

Conclusion: FRR systems with proposed 10 mm mesh screens would prove reliable and effective impingement reduction for SZC.

3.5 Conclusions

Studies of impingement reduction technologies for SZC demonstrated that two measures were both feasible and likely to reliably deliver reductions in the predicted losses of fish and crustacea. These are LVSE intakes and an FRR and both of these technologies are planned for the proposed SZC station.

With these measures fitted at SZC, the predicted reduction in impingement mortality compared with an unmitigated station based upon the expected performance of the LVSE intakes (Section 5.6) and the FRR system (Table 6) are shown in Table 3.

Table 3. Predicted reduction in impingement mortality for SZC fitted with LVSE intakes and FRR system compared.

Group	Example species	Impingement reduction
Pelagic fish	sprat, herring, anchovy, shad	62%
Demersal fish	bass, cod, whiting, grey mullet	77-79%
Epibenthic fish	eel, lampreys, sole, sand goby	92%
Shellfish	Crab, lobster, brown shrimp	92%

4 Relevant site features

The Sizewell site hosts SZA and SZB. SZA ceased operation at the end of 2006 and is being decommissioned. SZB is a direct-cooled nuclear power station using a pressurised water reactor design to generate an electrical output of about 1195 MW. The SZB intake and outfall structures are located inshore of the Sizewell Bank system (Figure 1). For SZB the volume of water extracted is 51.5 m^3 s^{-1} (51.5 cumecs). The intake structure consists of two intake heads, each initially leading to its own tunnel, which then join to form a single tunnel. Each head is octagonal and ~11.5 m across and is omnidirectional. The structure sits ~1.5 m above the seabed and the intake aperture is 3 m high. The tidal flows in the region are highly rectilinear and peak at 1 m s^{-1} on spring tides. During peak tides, a tidal streamline the width of the intake enters the intake, whereas at slack water the water is drawn from a radius around the intake.

The SZB intake was designed to not include any large superstructure that might attract fish and has a cap to limit drawdown from the surface. There are no screen bars or other devices that are designed to reduce fish entrainment or impingement at the intakes. There is also no provision for maintenance or internal access. The intake tunnel consists of nine square precast concrete caissons, each 4.82 m wide (internal) and 702 m long. Flow velocities in the tunnel are approximately 2.5 m s^{-1}, giving a passage time through the tunnel of approximately 5 min. The capped intake design was intended to ensure that warm, surface water was not drawn into the station, as well as to reduce the likelihood of there being a surface vortex. However, the capped design, by eliminating vertical water movement, was also expected to help fish avoid entrapment into the intakes, because fish are ill-equipped to respond to vertical water movements. Velocity caps were expected to be especially protective of pelagic species such as sprat and herring. Studies undertaken in March/April 1994 concluded that the B station impinged significantly fewer fish than the A station, which was not fitted with a velocity cap (Turnpenny and Taylor, 2000). The SZB discharge is through two tunnels that point offshore and upward with the discharge in the nearshore region ~150 m from the low tide mark (Figure 1).

The proposed SZC intakes will be low velocity side entry (LVSE) structures designed to reduce fish impingement. A total of 4 LVSE heads will be fitted with two heads fitted on each of the two intake tunnels. The intake heads will located approximately 3km offshore, on the eastern side of the Sizewell-Dunwich Bank in approximately 15m (ODN) depth (Figure 1). The detailed design of the intake heads is not yet complete but the performance of the design with the worst hydrodynamic performance has been used for this impingement assessment in order to envelope worst case impingement effects. This design has intake surfaces of the same size as those planned for Hinkley Point C (HPC) with the bottom of the intake surfaces being at more than1m off the seabed (as at HPC) in order to reduce abstraction of benthic organisms. The preferred outfall locations 09a and 09b marked are contingent on final engineering geotechnical assessments but will be there or slightly further offshore and in approximately 18m depth.

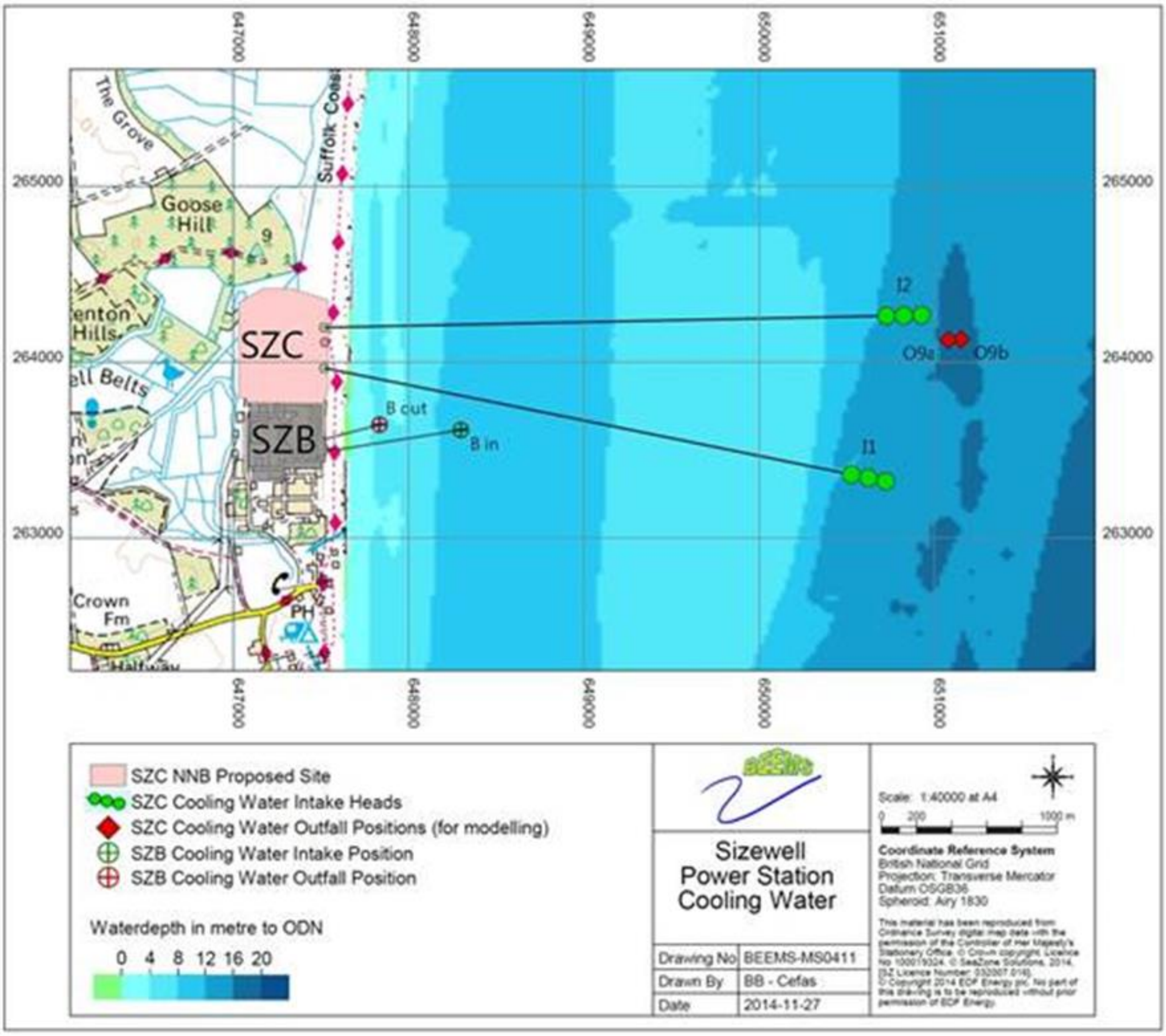

Figure 1 The coast at Sizewell, showing the locations of the intake and outfall for SZB and the proposed intakes and outfalls for SZC. The locations of three intake locations are shown for each SZC tunnel but only 2 heads will be fitted per tunnel with locations dependent upon geotechnical considerations.

5 Impingement Assessment Methodology

5.1 Introduction

To estimate the unmitigated impingement at SZC the assessment approach adopted in this report is to scale the measured impingement at SZB by the ratio of the cooling water volumes extracted by the two stations. The accuracy of the assessment depends upon whether:

- the fish community is the same at the location of the SZC intakes (approximately 3 km offshore) as at the SZB intakes (approximately 700 m offshore); and
- the SZC intakes will abstract the same amount of fish per cumec as SZB.

5.1.1 Differences in the abundance of fish at the SZB and SZC intake locations

The results of subtidal fishing surveys in the greater Sizewell Bay area are described in BEEMS Technical Report TR345). Ten demersal fishing surveys were carried out over a 4-year period. Sampling was conducted using two different fishing gears – a 2 m beam trawl and a commercial otter trawl. A coastal pelagic fish survey was also carried out in March and June 2015. These surveys found predominantly juvenile fish. Forty species were identified in the 2 m beam trawl catches, 25 in the commercial otter trawl catches. These fishing surveys found no significant spatial differences in the fish community nor the fish length distributions between the locations of the SZC and SZB intakes.

5.1.1.1 Bass distribution within Sizewell Bay

Bass impingement at SZB consists mostly of juvenile fish with few mature adults. From the CIMP survey from 2009- 2017 it is known that bass impingement at SZB takes place almost exclusively in winter (with 98.8% in the period November to March and 1.2% from April to October). In the period of lowest seawater temperatures (December to March) bass impingement is 96.1% of the annual total). It is well known that juvenile bass are attracted to the warm water outfalls of power stations in winter (Jennings *et al* 1991) and this has led to the creation of areas of restricted fishing around several UK power station outfalls. It was, therefore, expected that there would be differences in bass spatial density at Sizewell due to the SZB discharge but the extent of the area of attraction at Sizewell was unknown. To resolve this issue a highly targeted survey programme was undertaken to investigate bass distribution in the Greater Sizewell Bay (BEEMS Technical Report TR380). The aim of the programme was to quantify the impact of the SZB discharge upon the spatial distribution of bass and specifically to determine how the abundance of bass differed inside and outside of the SZB plume and whether there was a significant difference in abundance at the locations of the SZB and proposed SZC intakes.

In February 2016 a 5-day sampling programme was undertaken using an otter trawl known to be efficient at sampling bass. The high trawl opening allowed the sampling of fish from a larger part of the water column than a beam trawl (from just off the bottom to approximately 1m off the seabed) and the 4 mm mesh liner retained small individuals. February was chosen as this corresponds to the period of peak bass impingement at SZB (43% of the annual impingement total). Sampling was undertaken inside and outside of the Sizewell-Dunwich Bank, and close to and distant from the current and proposed intake/outfall locations of SZB and SZC, respectively. Forty-one tows were completed in the Greater Sizewell Bay. Three sampling sites were located outside the Sizewell-Dunwich bank (“offshore”) in similar depth strata and habitats. One site was in the area of the proposed SZC intake/outfall structures and the other two were some distance north and south of this. Five sites were located inside the Bank (“inshore”); the first immediately north of the SZB outfall; two about 1 km north and south of this, but within the SZB thermal plume; and two several km north and south and outside the plume. During the survey, 110 bass were recorded, ranging between 15.5 and 45 cm TL, with the majority being 2 y old (70.9%) followed by 3 y olds (14.5%) and the remainder up to 6 years of age (No 0 or 1 group fish were caught). The survey found:

a. A statistically significant majority of bass at Sizewell (105 bass or 95% of the bass caught) were recorded inshore of the Sizewell-Dunwich Bank.

b. A statistically significant increase in bass abundance was found near the SZB plume inshore of the Bank compared with other inshore stations to the north and south of the SZB outfall that were effectively outside of the influence of the SZB plume.

c. A statistically significantly greater abundance of herring and sprat were observed inshore of the Bank than offshore. There was no significant difference in the distribution of whiting across the Bank.

The sampling programme therefore confirmed previous observations that bass are attracted to warm water in winter. In particular, the abundance of bass at Sizewell was significantly different inshore and offshore of the Bank which would be expected based upon the significant difference in water temperatures near to the seabed at the two locations. The inshore sampling also demonstrated that the abundance of bass was significantly greater inside of the SZB plume than outside. These results provide confidence that the observed bass distribution was strongly associated with the presence of the SZB discharge plume and this has implications for the expected impingement rates for SZC which are discussed in Section 7.5.

5.1.2 Effect of the proposed SZC intake heads upon the expected impingement rate

SZC would be fitted with 4 low-velocity side-entry (LVSE) intake heads, mounted on the seabed approximately 3 km offshore. The proposed intake heads would be capped structures with the intake surfaces orthogonal to the direction of the tidal flows. The intakes are specifically designed to reduce the cross-sectional area available to intercept any fish being transported in the tidal flows. The reduction in cross-sectional area combined with the low intake velocity is predicted to substantially reduce the number of fish abstracted per cumec of abstracted seawater compared with SZB which is fitted with conventional omnidirectional intake heads with intake velocities that exceed the ability of most fish to avoid being abstracted. Modelling indicates that the SZC station will abstract 0.383 per cumec of the fish abstracted by SZB, because of the intake head design. The methodology used to derive this impingement reduction factor is described in BEEMS Scientific Position Paper SPP099 and is based upon the methodology proposed by the Environment Agency for impingement studies at Hinkley Point C.

The effect of the intake head design on the abstraction of organisms, is assessed by first multiplying all predicted values for SZC (unmitigated), by the factor of **0.383**. The full CIMP impingement assessment process is illustrated in Figure 2

5.2 SZB impingement data collection and collation

Impingement sampling at SZB was initiated in 2009 to provide information that could be used to predict the losses of the proposed SZC station. The sampling scheme consisted of sampling for 6 * 1-h samples in the daylight in addition to one * 18-h sample that was collected overnight. In each sample, the impinged material was sorted to species where possible, weighed and the fish fauna were measured. If subsampling was required, the data were raised to the individual sample first, before all 7 samples (six hourly, one overnight) were summed to give an estimate of the 24 hours of sampling. A total of 128 sampling visits was completed between February 2009 and March 2013. Each sample represented the estimated number and weight of fish that would have been impinged during the 24-h period, if the station was working at full capacity (i.e. 4 pumps in operation, which is not always the case during the year). The impingement data for 2009-2013 are described in four separate annual reports (BEEMS Technical Report TR120; TR196; TR215; TR270).

Sampling resumed in April 2014 and is ongoing. Prior to April 2014, the sampling methods were reviewed, particularly the need for the overnight sampling, to ensure that sampling was still appropriate to the data requirements. In general, the same sampling methods were adopted when data collection re-commenced. The only differences to sampling methodology were a change to the order in which the hourly and overnight samples were collected, the use of an Electronic Data Capture system (EDC) to improve the efficiency and reliability of data capture, and a change from measuring fish using Standard Length, to using Total length. Sampling has continued since April 2014. Between 2014 and 2017, a further 77 samples were obtained, and these were similarly raised to represent 24 hours with the station pumping at full capacity. Details of the sampling review, revised sampling methodology and data handling are given in BEEMS Technical Report TR339.

Both data sets were brought together to provide a single data set of 205 sampling visits, each providing information on the number and weight (and number at length for fish), of individuals impinged by the SZB station in 24-h at full capacity (BEEMS Technical Report TR339).

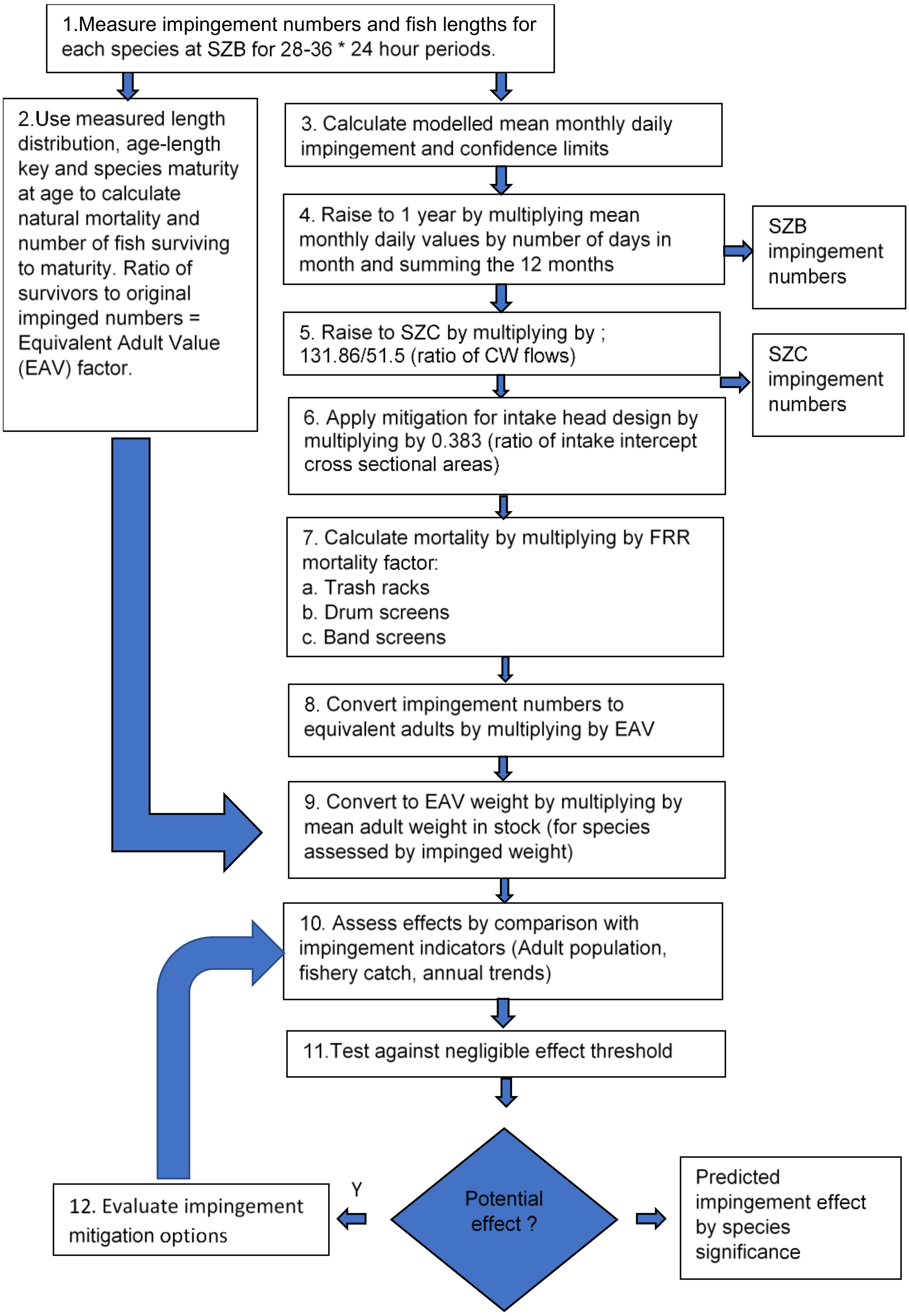

Figure 2 The SZC CIMP impingement assessment process

5.3 Estimated annual mean, minimum and maximum losses by the SZB station

Estimates of impingement for Hinkley Point C were based on a CIMP conducted at HPB in 2009 – 2010. For that dataset, sampling was conducted over 40 visits throughout the year. Estimates of annual impingement were calculated by first summing all samples from each quarter of the year and raising the quarterly total by the ratio between the number of days in the quarter and the number of sampling visits. The quarterly totals were summed to give an annual impingement estimate. Variability was estimated by bootstrapping the dataset – randomly selecting a subset of visits from each quarter and repeatedly estimating the total annual impingement to give 95 % confidence estimates around the mean value. This was possible because the number of samples available was evenly distributed thought the sampling year.

The SZB CIMP dataset is extensive, spanning 9 years and 205 samples. Ideally, with this time series, we would calculate and present estimates for impingement for each year separately, so that year-year variation could be observed. Impingement estimates for each year would be calculated using the same methods described for Hinkley Point, i.e. quarterly raising and the use of bootstrapping to provide confidence estimates. However, Hinkley Point B has dual reactors which means that even during outages there are rarely periods when the station is not abstracting seawater and this allows a near continuous impingement record. Sizewell B has a single reactor and therefore during outages no seawater is abstracted and therefore the impingement record is discontinuous and the Hinkley Point assessment methodology cannot be used. In particular, very little sampling occurred in 2013 (sampling was suspended in March 2013), and there are large sampling gaps particularly in the later sampling years (e.g. quarter 1 in 2014 and 2015). This was largely due to outages when no sampling could take place (Table 6). Therefore, raising the data quarterly would bias those species that show strong seasonal patterns in their impingement abundance (a frequent occurrence), leading to under or over-estimates of impingement. For example, due to the lack of samples in quarter 1 in 2014 and 2015, the numbers of bass and thin-lipped grey mullet recorded was small. Raising these years to an annual estimate would lead to significant underestimations of these two species in those years, which could be incorrectly interpreted as a decrease in abundance for those years.

Although the quarterly raising and bootstrapping approach could be used for some years with more evenly distributed sampling, it could not be consistently applied across the whole dataset. Further, there is no way of selecting any single year to represent impingement sampling at SZB. Consequently, a different approach was required to estimate annual impingement at Sizewell.

Table 4 Summary of the number of sampling visits to SZB completed between 2009 and 2017

	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
January		2	5	1	2			2	3	15
February	3	4	2	3	3			3	2	20
March	4	2	2	1	2			2	2	15
Q1 total	**7**	**8**	**9**	**5**	**7**	**0**	**0**	**7**	**7**	**50**
April	3	3	2	2		3	1		2	16
May	3	3	2	3		2	3		1	17
June	3		2	2		2	2	2	3	16
Q2 total	**9**	**6**	**6**	**7**	**0**	**7**	**6**	**2**	**6**	**49**
July	4	2	2	2		3	3	2	3	21
August	4	2	3	3		2	2	2	3	21
September	1	3		2		1	2	3	1	13
Q3 total	**9**	**7**	**5**	**7**	**0**	**6**	**7**	**7**	**7**	**55**
October		4	3	3			3	2	1	16
November	7	3	3	2			2	3		20
December	4	3	2	2			2	2		15
Q4 total	**11**	**10**	**8**	**7**	**0**	**0**	**7**	**7**	**1**	**51**
Total	**36**	**31**	**28**	**26**	**7**	**13**	**20**	**23**	**21**	**205**

5.4 Statistical method used to derive annual impingement estimates at Sizewell

Impingement estimates were made by fitting a statistical model (developed in R software) to the impingement data. Each species was assessed separately and there is no aggregated result by habitat or trait. Sampling was carried out on 205 different days between 4th Feb 2009 and 5th October 2017, and if a species was not encountered on a sampling day it was marked as an absence (0) for that day. For some species this resulted in a timeseries of mainly zeros.

The model chosen to characterise each species was different based on the number of occasions where an organism of that species was present. For species where presence was relatively continuous, a more complex model was applied which could assess how the number of organisms impinged varied from month-to-month and year-to-year (ZINB model). For species where absences were generally more common than presences, the model was restricted to investigating only the month-to-month variability as there was not enough data to investigate interannual variability (NB model).

ZINB models are known as Zero-Inflated Negative Binomial models and are computationally more complex because they consist of two parts to handle data with many zeros. Zero-Inflated Negative Binomial models generate a presence-absence model as well as an abundance model and combine the two models into one to return an estimate of abundance. This model asks how likely any presence is at a certain point in time, and how abundant is it likely to be at this point in time if it is likely to be present. Therefore, ZINB model models are the preferable tool for characterising a dataset with large number of zeros and the resulting estimate should be more accurate for this model than for NB models.

NB models are Negative Binomial models and are simpler because (a) they consist only of the abundance part of the model and (b) because they are not set up to look at the changes in abundance from year-to-year (interannual variability). This model therefore asks how abundant a species is likely to be during a certain month. The resulting estimate should be less accurate for this model.

Where possible, the ZINB model was used, but this was not always possible. For species where there were less than 22 out of the 205 sampling occasions, there were not enough presences for this model to be used since this model aims to identify both variability between years and variability caused by time of year. To do this, a relatively large (~10% or greater) number of presences is needed, and the presences need to be distributed amongst the various years which was not always the case. Where this is not the case, a ZINB model will not converge, meaning the effect of year and month cannot be obtained from the model.

If the ZINB model assessing the effect of year and month could not be used, the temporal resolution was reduced, making the model more likely to converge. The time data were passed to the model in coarser time periods. For example, instead of assessing each month as a separate time-step, each two months (one sixth of a year) was used. If there was still too little data for the model to converge, three months (one quarter of a year) was used as a time-step. If the model still did not converge (as was the case for any species where there were less than 22 out of the 205 sampling occasions), the simpler NB model was used. Therefore, within the ZINB models, there are 3 different levels of resolution depending on how much data was available: every month, every bimester, and every trimester. Each species was assessed to the best resolution possible, ideally monthly. All NB models used have a monthly resolution but did not assess the influence of year (no random variance caused by interannual variability).

Regardless of the timestep used, the influence of year was treated similarly for all ZINB models. A year was defined from February to the following January and was separated into two periods which were treated as separate events from February-July and August-January, contributing a random variance to the model, and to recognise that anomalously high abundances in one half of the year may not be always be coupled with anomalously high abundances in the second half of the year. Although data collection spanned a 9-year period, data from February 2013 to January 2014 was excluded from this analysis, as only limited sampling took place during that period.

The final model outputs provided (for each species) a mean daily number of individuals impinged for each month separately, along with lower and upper values that corresponded to 95 % confidence intervals.

5.5 Predicted annual mean, minimum and maximum losses by the SZC station

The predicted (unmitigated) losses that will be incurred by the SZC station were calculated by simply raising the mean, lower and upper estimates for SZB by the ratio of the two pumping capacities (i.e. 131.86/51.5 for each species).

5.6 Effect of the intake head design

The predicted effect of the proposed LVSE intake head design on the abstraction of organisms, was assessed by first multiplying all predicted values for SZC (unmitigated), by the factor of **0.383**. (Section 5.1.2)

5.7 FRR system mortality

The proposed drum screen mesh size for SZC is 10 mm allowing a direct comparison with the current mesh size employed at SZB. In the best practice guide for screening for intakes and outfalls Environment Agency (2005) recommend *"mesh size should be as small as is practical, and of no more than 6 mm aperture"*. However, Environment Agency (2010) acknowledge that at coastal sites a 6 mm mesh may lead to the risk of ctenophore blockage during summer months. Gelatinous ctenophores would more readily distort under drum screen conditions and squeeze through a 10 mm mesh screen (Environment Agency, 2010). After a consideration of clogging risk EDF Energy have proposed that SZC's fine filtration systems should have 10 mm mesh. The trash rack bar spacing might then be relaxed to 75 mm bar without exceeding design criteria for the drum screens.

5.7.1 Trash rack mortality

Located immediately before the drum and band screens, will be a series of trash racks, designed to protect the screens from debris but which will also prevent the passage of large fish. The racks, which will have a bar spacing of 75 mm can be raised for cleaning and any material that cannot pass through the bars will be sent to the debris recovery building (HCB). The debris recovery building has another trash rack with 200 mm bar spacing and fish that pass through this secondary trash rack will be returned to sea via the FRR tunnel. Any that remain (i.e. cannot pass through 200 mm) will go to waste. It is assumed (subject to review of the SZC design), that all organisms that cannot pass through the primary trash rack (75 mm bar spacing) will suffer 100 % mortality, even if they would then pass the secondary trash.

Each of the 24 key species has a different body shape and maximum size, and therefore the size at which an individual will be able to pass will depend on its species. The proportion of the total number of that species that will not pass will depend on its size distribution in the cooling water systems.

5.7.1.1 Calculation of annual length distributions

The final impingement dataset also included the number at length of the key species, by sampling visit. These were used to provide an annually-raised length distribution for each of the key species. The number of individuals in the annually raised length distribution equalled the number of individuals estimated to have been impinged by SZC per year.

Several steps were required to account for seasonal growth in the length distributions:

- First, the samples were grouped by month, and the numbers at length were summed. The total numbers at length were then divided by the number of samples in that month. This provided a standardised length distribution for each month separately.
- Next, the 12 monthly length distributions were summed, and their total numbers at length were divided by 12 to give a single standardised length distribution representing one year.

- Finally, the numbers at length were raised to an annual total by multiplying by (number of individuals impinged by SZC/number of individuals in the standardised length distribution).

(These annually raised length distributions were also used in the calculation of the EAVs - see BEEMS Technical Report TR383).

5.7.1.2 Calculation of the cut-off for passing through the 75 mm bar spacing.

For each species, its ability to pass through the 75 mm trash rack will depend on its width, which can be calculated from its length. However, HPB already has trash racks fitted with a 75 mm bar spacing, and length data show that for some species (e.g. cod and bass), even fish with a calculated width > 75 mm can pass through to the drum screens (BEEMS Technical Report TR456). This indicates that the passage of a fish through the trash racks may not simply be limited to its calculated width. This has been accounted for in calculations on the proportion of a species that will or will not pass the 75 mm bar spacing. Species were grouped depending on how their passage through the trash racks was assessed:

- Group 1. For some species (e.g. sand gobies), expert judgement was used to conclude that all individuals would pass, irrespective of size (i.e. proportion retained by the trash racks = 0).
- Group 2. For all other species, the width of the largest observed individual was calculated. Group 2 species are those whose calculated width of the largest observed individual was ≤ 75 mm (e.g. river lamprey *Lampetra fluviatilis*). It was assumed that no individuals will be retained by the trash racks.
- Group 3. For almost all the remaining species the calculated width of the largest SZB fish was ≥ 75 mm, indicating that a proportion of individuals will not pass. Most of these species were recorded during impingement sampling at HPB, which is already fitted with 75 mm trash racks. For this report, the length of the largest observed individual to pass through the 75 mm HPB trash rack was used as the maximum size that would also pass through the proposed 75 mm SZC trash rack. The proportion of a species that would be retained on the trash rack was calculated from the annually raised SZB length distributions of that species (Section 5.7.1.1).
- Group 4. For two species (sea trout and Allis shad), the calculated width of the largest SZB fish was ≥ 75 mm, indicating that a proportion of individuals will not pass through, but the species was not recorded at HPB. The approach used for Group 3 fish could not be used. In this case, the length of a fish with a width of 75 mm was calculated as the maximum size that would pass through the trash racks. Given that for many species, individuals of a calculated width were able to pass through the trash racks, this is likely a conservative approach.

For each species, the proportion of fish that would be retained by the 75 mm trash rack was applied to the number of fish that passed through the intake head, giving the number of fish lost to the trash racks (Table 5). Fish passing through the trash racks will go on to encounter the drum or band screens.

Table 5 Proportion of fish, by species that will not pass through the 75 mm wide trash racks, and the length size used for the cut-off

	Calculation type	Length of largest SZB fish (mm)	Calculated width of largest SZB fish (mm)	largest observed HPB fish	Calculated length at 75 mm width (cm)	Proportion not passing trash rack	Comment
Sprat	Group 2	260	53			0.000	All observed fish will pass
Herring	Group 3	445	94	224		0.715	Use largest observed HPB fish length (impingement datasets)
Whiting	Group 2	525	48			0.000	All observed fish will pass
Seabass	Group 3	850	232	657		0.0002	Use HPB largest observed individual (TR456)
Sand goby	Group 1	100	NA	74		0.000	All observed fish will pass
Dover sole	Group 3	440	124	449		0.000	Use HPB largest observed individual (TR456)
Dab	Group 3	380	160	139		0.419	Use largest observed HPB fish length (impingement datasets)
Anchovy	Group 1	230	NA	169		0.000	All observed fish will pass
Thin-lipped grey mullet	Group 3	425	91	524		0.000	Use largest observed HPB fish length (impingement datasets)
Flounder	Group 3	425	119	339		0.031	Use largest observed HPB fish length (impingement datasets)
Plaice	Group 3	355	150	382		0.000	Use HPB largest observed individual (TR456)
Smelt	Group 1	250	NA			0.000	All observed fish will pass
Cod	Group 3	895	133	709		0.006	Use HPB largest observed individual (TR456)
Thornback ray	Group 3	765	503	952		0.000	Use HPB largest observed individual (TR456)
River lamprey	Group 2	405	25			0.000	All observed fish will pass
European eel	Group 2	895	56			0.000	All observed fish will pass
Twaite shad	Group 3	490	103	299		0.883	Use largest observed HPB fish length (impingement datasets)
Horse mackerel	Group 2	355	71			0.000	All observed fish will pass
Mackerel	Group 2	405	69			0.000	All observed fish will pass
Tope	Group 2	625	63			0.000	All observed fish will pass
Sea trout	Group 4	530	121	not at HPB	33	1.000	Calculate length at 75 mm width
Allis shad	Group 4	610	128	not at HPB	36	1.000	Calculate length at 75 mm width
Sea lamprey	Group 2	795	50	807		0.000	all observed fish will pass

5.7.2 FRR survival

Well-designed FRR systems have been reported to achieve 80−100 % survival rates for robust species such as eel *Anguilla anguilla* , plaice *Pleuronectes platessa* and flounder *Platichthys flesus*, and moderate rates (~50−60%) for demersal species such as the robust gadoids (e.g. cod). However, survival rates for delicate pelagic species such as herring, sprat and shad (twaite shad *Allosa fallax* and Allis shad *A. alosa*) are usually low (<10%, Environment Agency, 2005). The proposed FRR system for SZC at both the band and drum screens has been designed to achieve high rates of survival for European eels (eel, *A. anguilla*) and lamprey (river lamprey and sea lamprey *Petromyzon marinus*), and it is expected that survival rates for other epibenthic (flatfish including rays) and demersal species will also be higher than achieved in older designs. For the purpose of this study the conservative FRR recovery rates given in the Environment Agency science report (2005) are used as the basis for FRR survival rates.

However, the estimates of FRR survival have been modified to account for the SZC location and station design. The SZC FRR system will discharge inside the Sizewell-Dunwich Bank and there is potential for a few fish discharged from the SZC FRR to be subsequently taken up by the SZB intake. Modelling confirms that this risk is negligible at the proposed SZC FRR outfall locations (BEEMS Technical Report TR333), but it is conservatively assumed that any such fish will suffer 100 % mortality during their passage through SZB. The SZC mortality is increased to compensate for this effect (Table 6).

As well as using drum screens for the main cooling water flow, SZC will be equipped with band screens to protect the essential and auxiliary cooling water systems. Due to their safety role, the band screens must be seismically qualified and capable of surviving an aircraft impact. The normal operating mode of such band screens is to be stationary and to only rotate intermittently at 6 hourly intervals unless significant clogging occurs. It is possible to fit an FRR system to the band screens, but this would have little to no purpose if the screens only rotated every 6 hours. It would, however, serve a purpose if the screens rotated continuously. The band screen manufacturer considers that the screens could be operated continuously at a ‘creep’ rotation speed of 0.5 metres per minute; any faster would have unacceptable implications for the operational life and maintenance of the safety-classified band screen motor and chains. For HPC, it was assumed that with the size of the band screens, at a rotation speed of 0.5 m min^{-1}, the fish retention time in the band screen fish buckets would be approximately 33 minutes at Mean Sea Level (MSL) and 50 minutes at the Lowest Astronomical Tide (LAT). As a conservative assumption, it was considered that demersal fish would not survive this time in the fish buckets. However, with a fish-friendly design ensuring they cannot fall out of the buckets during the predicted retention time, robust epibenthic species such as flatfish, eels and lamprey are expected to survive. The tidal range at Sizewell is lower than at Hinkley Point and the size of the SZC drum and band screens will therefore be smaller leading to reduced rotation time and reduced fish retention time in the fish buckets which will enhance survival. In this assessment we have assumed, as a conservative estimate, the same FRR survival estimates that were applied to the HPC band screens; i.e. that the fish survival percentages for epibenthic species will be the same for drum screen and band screen FRR systems, but that the survival of demersal species in the band screens will be 0 % (Table 6). This conservative assumption may be revisited when further information is available on detailed station design.

To calculate drum screen and band screen losses, the number of fish remaining after passage through the trash racks was apportioned into those that will encounter the drum screens and those that will encounter the band screens based on the proportion of water flowing through each (drum screens = 91 %; band screens = 9 % of the cooling water). This is considered a reasonable approach as the approach velocity is identical for all of the SZC drum and band screens. The proportion of numbers of fish that would be retained by the drum and band screens was calculated for each species separately.

5.7.3 Other factors which could potentially affect FRR survival rates

In principle two issues that have not yet been discussed in this report could affect the survivability of impinged fish in the SZC FRR system:

a. Overloading of the SZC FRR system by dead fish that do not survive the recovery process (mostly pelagic fish such as sprat and herring) causing fatal oxygen depletion in parts of the system where fish densities are the highest (the drum screen buckets)

b. Clogging of the SZC FRR system by ctenophore blooms in summer

The SZC seawater filtration system is designed to protect the CW condensers and heat exchangers from blockage from marine organisms. The system was designed based upon operational experience at EDF Energy coastal power stations without impingement mitigation technology and as such there was no assumption in the design of the filtration system for reductions in fish impingement due to the SZC Low Velocity Side Entry (LVSE) intake heads. The SZC filtration system has been designed to have considerable capacity to respond adaptively to extreme fish densities at the drum and band screens by increasing the rotation rate of the screens such that organisms are returned to sea via the FRR system at a faster rate. For example, the drum screen rotation rate can be increased from the normal 2.5 m min^{-1} to 10 and then 20m min^{-1} in response to different screen loadings i.e. the system can provide an 8-fold increase in filtration capacity under extreme conditions. The band screens are even more adaptable and can provide a 20-fold increase in filtration capacity by increasing the rotation rate from 100 minutes per rotation to 20 and then 5 minutes.

The main clogging risk at Sizewell are from winter sprat inundations and particularly from summer ctenophore blooms. As noted in Section 5.7, after consideration of the clogging risk from ctenophores, EDF Energy is proposing to to fit 10mm mesh filters at SZC. Operational experience at Sizewell B has shown that such a mesh size has avoided problems of clogging from either ctenophores or sprat. In terms of relative risk, SZC would be at much lower risk than SZB from sprat inundations due to the use of LVSE intake heads at SZC which it has been calculated will reduce sprat impingement per cumec by a factor of 0.38 (Section 5.1.2). A study for HPC (BEEMS Technical Report TR493) determined that there was a negligible risk to fish survival in the HPC FRR system due to dead impinged fish (overwhelmingly sprat). The rotation path lengths of the SZC drum and band screens will be smaller than those deployed at HPC due to the smaller tidal range at Sizewell and therefore fish residence times in the fish buckets will be shorter. The risk to fish survival from dead fish in the fish buckets is, therefore, expected to be lower at SZC than at HPC and therefore also negligible

Ctenophores are present for most of the year at Sizewell but only occur in dense blooms in summer (typically in June). The proposal to use a 10mm mesh means that the majority of entrapped ctenophores will be entrained rather than impinged. There have not been any shutdowns at Sizewell B which also uses 10mm mesh filtration due to gelatinous species. With negligible clogging risk there remains the question of whether the loading of ctenophores would reduce fish survivability in the SZC FRR system. As can be seen from Figure 3 the weight of fish impinged during summer ctenophore blooms is extremely small. Much smaller peaks in ctenophore abundance occur at other times of the year but the additional ctenophore biomass is much smaller than the peak fish biomass that the FRR system can handle with negligible risk to fish survival.

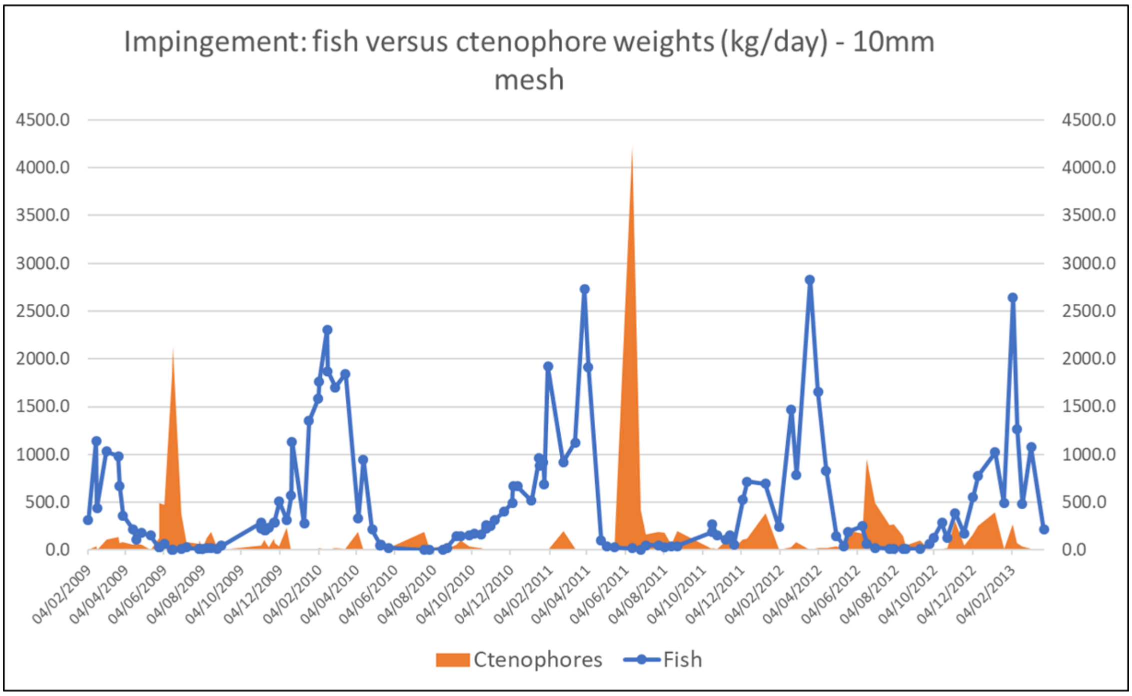

Figure 3 Comparison between estimated daily impingement weights for ctenophores and fish from SZB CIMP data.

Clogging of the SZC FRR system and the consequent risk to fish survival of recovered fish is, therefore, considered to be negligible.

5.7.4 Values used for FRR survival in the SZC impingement assessment

The predicted total mortality suffered by each species passing through the SZC cooling water systems, considering FRR survival, was calculated as:

Total mortality = Trash rack losses + band screen losses + drum screen losses

The results are shown in Table 6.

Table 6 Predicted FRR mortality by species through the SZC drum and band screens

	Proportion lost		
	Drum	Band	Species group
Sprat	1.000	1.000	pelagic
Herring	1.000	1.000	pelagic
Whiting	0.506	1.000	demersal
Bass	0.506	1.000	demersal
Sand goby	0.206	0.206	epibenthic
Sole	0.206	0.206	epibenthic
Dab	0.206	0.206	epibenthic
Anchovy	1.000	1.000	pelagic
Thin-lipped grey mullet	0.506	1.000	demersal
Flounder	0.206	0.206	epibenthic
Plaice	0.206	0.206	epibenthic
Smelt	1.000	1.000	pelagic
Cod	0.560	1.000	demersal
Thornback ray	0.206	0.206	epibenthic
River lamprey	0.206	0.206	epibenthic
Eel	0.206	0.206	epibenthic
Twaite shad	1.000	1.000	pelagic
Horse mackerel	1.000	1.000	pelagic
Mackerel	1.000	1.000	pelagic
Tope	0.206	0.206	epibenthic
Sea trout	0.506	1.000	demersal
Allis shad	1.000	1.000	pelagic
Sea lamprey	0.206	0.206	epibenthic
Salmon	0.506	1.000	demersal

5.8 EAV conversion factors

Equivalent Adult Values (EAVs) are used to adjust the number of lost juveniles to a corresponding number of lost adults. This adjustment is required because juveniles suffer higher natural mortality when compared with adults of the same species, and the loss of one juvenile does not result in the loss of one adult. Conversion of the numbers impinged to the equivalent number of adults is a simple matter of multiplying the former (the total impingement mortality) with the appropriate EAV value for each species. The EAV values used were calculated using a method developed as part of the BEEMS programme (BEEMS Technical Report TR383). The reliability of the EAV calculation method has been extensively evaluated for HPC studies in BEEMS Technical Report TR456 and the calculation method used at Sizewell is the same as that used for HPC, in particular the natural mortality corrections applied are the same. These calculations use data on the size distribution of the impinged fish along with information on size at age and size at maturity. Since the model outputs giving rise to the SZB estimates and SZC predictions were based on the combined 2009 – 2017 data, only a single EAV could be calculated for each species (Table 7) that used the size distribution from the whole sampling period (see Section 5.7.1.1 for details on the calculation of the size distribution).

All methods for calculating EAVs are subject to biological uncertainties. The method used for this assessment and described in BEEMS Technical Report TR383 is based upon the best available science at the time of writing and uses peer reviewed input parameters appropriate to the local populations at Sizewell.

A key advantage of this method is that the approach represents a method for calculating EAV that can be widely applied to many species and requires data that are more readily available than the method described by Turnpenny (1989) that has been used for some previous power station effects analyses. Turnpenny (1989) defined the EAV as “the average lifetime fecundity of an adult that has just reached maturity which is required to replace that juvenile”. To calculate the EAV curve or construct the associated life table for a given species, a variety of parameters are required, such as the average fecundity of each female age class, the number of age classes in the population and the average fecundity of mature females of the final age class. Many of these parameters are difficult to reliably estimate, even to orders of magnitude. Consequently, Turnpenny (1989) only provided EAV life tables/curves for six commercial species (cod, whiting, plaice, Dover sole, dab and herring) and the accuracy of these values is uncertain.

5.8.1 Discussion of the Spawner Production Foregone method for calculating EAVs

For HPC assessment purposes an alternative method for calculating EAVs has been suggested by stakeholders using the ‘Spawner Production Foregone’ (SPF) method of deriving equivalent adult value factors. The use of this method has been occasionally attempted in the past for assessing power station effects (predominantly in the USA). The SPF approach calculates the total loss to the population as the sum of equivalent adults lost from the spawning population in that year, plus the future spawning potential of lost fish that would have matured in previous years. In so doing the assumption is made that long lived fish could have spawned in multiple future years after they reached maturity and therefore some fish populations could have an EAV value of greater than 1, whereas the Cefas method has a maximum EAV value of 1. The major assumption of the SPF methodology is that long lived species would survive to spawn in multiple future years after reaching maturity (for short lived species the differences between the results produced by the SPF and Cefas EAV methodologies can be small dependent upon the impingement catch distribution). However, for many species this is an invalid assumption as after reaching maturity (often before reaching maturity), the fish become at risk of fishing mortality which is frequently much greater than natural mortality such that few fish live to spawn on multiple occasions; this effect is particularly pronounced for species such as cod. Since fishing mortality can and does occur before the age of maturity, the Cefas method described in BEEMS Technical Report TR383 for calculating EAVs can also overestimate the EAV for populations with large numbers of fish at or near maturity, however the potential error in ignoring fishing mortality is much less than with the SPF method.

The other significant issue with the SPF method is that ICES fisheries assessment models do not account for production foregone as they simply reflect the Spawning Stock Biomass (SSB) of fish alive at a particular point in time. So, unless the time dimension is kept for the SPF method (which combines several time periods), it is difficult to see how the population effects derived using SPF EAVs are comparable with ICES SSBs, particularly as the SPF method also ignores fishing mortality (something that ICES stock assessments fully account for). Simply put the TR383 method computes the value of a lost mature adult as 1 fish lost from the Spawning Stock Biomass, it does not try to account for the potential future production from that fish if it lived to spawn again. As such it is compatible with the methods used to assess the effects of fishing and the derivation of the spawning stock biomasses by ICES. Comparison with ICES stock assessments is the standard method of assessing the effect of fishing or power station entrapment and the ability to undertake reliable, quantitative comparisons of power station mortality against SSB is fundamental to the assessment of SZC effects. The use of the SPF method has, therefore, not been taken forward in this assessment.

5.8.2 Potential detail change to the EAV calculation methodology in TR383

The effect on EAV results if the calculation stopped at 50 % maturity and not the 100% maturity used in TR383 has been queried. The rationale for this question is that the Turnpenny (1989) method is based upon ages at 50% maturity as are some stock assessments, and a revised methodology could be more conservative.

It was considered that such a change probably wouldn't materially affect the predicted SZC losses but Cefas examined whether this initial view was justified. The potential effect of such a change was checked for three different types of fish taxa with different life cycle parameters (bass, cod, herring) and calculated EAVs increased by 3.6%, 11.5% and 4.3% resulting in consequential changes in predicted entrapment losses by the same percentage. For example, the EAV for bass would change from 0.224 to 0.232 resulting in an increase in unmitigated impingement losses from 1.32% SSB to 1.37% SSB and cod losses would increase from 0.0035% SSB to 0.0039% SSB. Such changes are considered immaterial to the SZC assessment and have not, therefore, been included in this assessment report.

5.9 Conversion from EAV numbers to equivalent weight

As most stock information (particularly for commercially-exploited species) is given as weight rather than number of fish, the EAV numbers of impingement losses were converted to EAV weights (t), using values of mean weight per species (Table 7). The preferred method of calculation would have been to calculate the mean weight of adults only for all species. However, the final method used depended on the data available for that species.

For some species where international stock assessments are carried out, the datasets contain the mean weight of fish in each age group, the catch numbers in that age group and the proportion of fish mature in each age group. In this case, the numbers of mature fish caught in each age group was calculated by multiplying the number caught in the age group by the proportion that were mature. Multiplication of the number mature in the age group by the mean weight of an individual in the age group provided the total weight of fish in the age group. The weight of all fish in the age groups was summed and then divided by the total number of mature fish to give a mean weight of each mature fish.

However, this level of data is not available for all species, and alternative methods were used for these species. For salmon and trout for example, the EA catch statistics reports (Table 8) give the average weight of individuals of each species caught in the fishing year, based on catch returns, and these values were used. For lamprey the mean weight of fish entering the Ouse was used, as it was assumed that these fish are entering the estuary to spawn, and are therefore mature.

In each case, judgement was based on the data available.

Table 7 EAV metrics and mean weight of individuals used to convert the numbers impinged to adult equivalent numbers and weights at SZC. See BEEMS Technical Report TR383 for full EAV calculations. Species where an EAV could not be calculated are highlighted in yellow and the impingement losses are overestimates

Species	**EAV**	**Mean weight per individual (kg)**	**Data source for mean weight**
Sprat	0.751	0.011	ICES catch weight at age data
Herring	0.715	0.189	ICES catch weight at age data
Whiting	0.356	0.286	ICES catch weight at age data
Seabass	0.224	1.531	ICES catch weight at age data
Sand goby	1.000	0.002	Mean size of gobies impinged at SZB
Sole	0.213	0.214	ICES catch weight at age data
Dab	0.445	0.041	ICES catch weight at age data
Anchovy	0.974	0.021	Mean weight of anchovy the Bay of Biscay catches
Thin-lipped grey mullet	0.083	0.520	Estimated from weight at 75 % maturity (age 3.5)
Flounder	0.462	0.082	Estimated from weight at 21 cm (fully mature - ICES)
Plaice	0.345	0.246	ICES catch weight at age data
Smelt	0.761	0.017	Estimated from length at maturity (knife-edge)
Cod	0.359	2.602	ICES catch weight at age data
Thornback ray	0.193	3.193	Mean length of market sampled fish in southern N. Sea

River lamprey	1.000	0.079	Mean weight of lampreys entering Ouse fishery in 2018 – regulator comment to Version 1 of this report
European eel	1.000	0.329	Mean of a mature female (568.9 g) and male (89.9 g) adult (Aprahamian, 1988), assuming a 50:50 sex ratio
Twaite shad	1.000	0.313	Calculated from adult size of 32 cm
Horse mackerel	1.000	0.140	Mean weight in the catch
Mackerel	1.000	0.319	ICES catch weight at age data
Tope	1.000	6.900	Modal length of fish in observer catches = 100 cm
Sea trout	1.000	1.734	from EA catch statistics
Allis shad	1.000	0.572	Calculated from adult size of 40 cm
Sea lamprey	1.000	1.212	Weight of single individual (length = 79 cm) impinged at SZB
Salmon	1.000	3.684	from EA catch statistics

Note: The use of an EAV of 1 results in an overestimate of impingement effects for most species e.g. it is known that the impinged eels at Sizewell were yellow eels that will suffer additional natural mortality before reaching the adult silver eel stage. Similarly, not all of the impinged twaite shad were adults.

5.10 Evaluating the effect of SZC impingement losses – comparison with ICES stock estimates

Fish mortality due to impingement at SZC can be considered as a form of fish harvesting.

Fish stocks in the Northeast Atlantic are managed partly through the EU Common Fisheries Policy (CFP), whose objective is to maintain or rebuild fish stocks to levels that can produce their maximum sustainable yield (MSY). The International Council for the Exploration of the Sea (ICES) advises public authorities with competence for marine management including the European Commission (EC). ICES was established in 1902 and its advice integrates the work of approximately 5,000 scientists from over 700 marine institutes in the organisation’s 20 member countries and beyond.

ICES’ advice is produced through a process which is set up to ensure that the advice is based on the best available science and data, is considered legitimate by both authorities and stakeholders and is relevant and operational in relation to the policy in question.

The basis for the advice is the compilation of relevant data and analysis by experts in the field, normally through an expert group which includes core researchers in the field. This analysis is peer reviewed by scientists who have not been involved in the expert group and have no direct interest in the matter. To support the stock-by-stock management system, ICES provides advice on fishing opportunities and stock status for individual stocks.

For many species, annual analytical assessments are carried out that utilise information on life history, fishing effort and catches to assess the size of the stock, in particular the spawning stock biomass (SSB). To undertake an assessment ICES scientists have to evaluate information on the life history and fishery characteristics of a stock to determine the most scientifically appropriate geographical area in which to assess the stock (the stock unit). Stock assessments are carried out by Expert Groups (also known as Working Groups), each of which is responsible for a specified number of species and stocks. The outcomes of the assessments are released as official ICES advice.

Wherever possible, in cases where a full analytical assessment is available for a species impinged at Sizewell, and the SSB has been estimated, the SZC predicted impingement losses were compared with the ICES estimated SSB for the stock area as these estimates provide the most robust peer reviewed scientific evidence. As the annually raised impingement numbers were based on data collected in 2009 – 2017, comparisons were made with the average SSB values over this time.

This is the preferred measure for determining the effects of fish impingement (and entrainment) losses and this is how the much larger environmental effects of fishing are internationally assessed and managed. It must be emphasised that the comparison with the SSB in the assessment year(s) conducted in this report are not a full fisheries population assessment and in stocks where the population biomass is heavily dependent upon new recruits which suffer a high rate of natural mortality this simple measure can provide a misleading overestimate of impingement effects. However, a full population assessment is both unnecessary and disproportionately difficult to undertake for species where impingement effects are negligible. If the predicted effects of impingement on a particular species were above the precautionary 1% negligible effects threshold used in this report (Section 6) a full population assessment is one of the steps that could be considered to reduce uncertainties and to determine if there was in fact any risk to the sustainability of the population.

5.10.1 Are ICES stock units appropriate for assessing the effects of SZC on fish populations?

To undertake their stock assessments ICES' scientists have identified biological stock areas that describe the distribution of a stock. These may be different from the areas defined by the EU, for example, for the management of fishing quotas and technical measures. Identification of appropriate stock boundaries has been a central theme of ICES' coordinated effort since its formation in 1902 and major advances in understanding have, and continue to be, made.

SZC stakeholders have queried the appropriateness of some of the existing stock units, particularly for bass which has one of the largest stock units of the key fish species included in the SZC effects assessment. In particular, they have queried whether the stock areas being used for the assessment of impacts to certain species consider the impact to local sub-populations given that several papers (including papers produced by ICES) provide evidence of sub-populations and more complex heterogeneous population structures.

There is extensive literature focused on specific aspects of fish migratory behaviour and this information is periodically reviewed by the appropriate ICES working groups. The questions then are do the specific behaviours described in the research papers change the weight of evidence used to assign stock units for management purposes? This section focuses on how ICES determines stock identity for fisheries management purposes.

As a result of decades of research, it is clear that the population structures of marine species fall along a continuum from panmictic (e.g. European eel, *Anguilla anguilla*) to numerous distinct sub-populations (e.g. North Sea herring, *Clupea harengus*) with the majority of species exhibiting complex structure. In the open sea, the sub-populations of many species mix to a considerable extent; especially during summer feeding and on nursery areas, with harvesting affecting multiple components of the overall population simultaneously. Spawning areas have been delineated for many fish species, but determination of the amount and timing of mixing is much more complex. Creation of appropriate stock units to manage harvesting has to consider all of these issues and it is recognised that in so doing harvesting may not always be optimal.

The current ICES stock boundaries are the result of decades of research and are inevitably compromises that try to embrace known uncertainties. Stock unit boundaries are not changed without careful weighing of the evidence for the need and the value to be gained from a change. However, stock boundaries are subject to periodic review and do change as a result of acquired evidence; e,g. North Sea sandeel where understanding of the vulnerability of largely sedentary post-settlement sub-populations led to a reorganisation of the original four stock units into seven units; with some stock units becoming larger and some smaller. For some species it is known that there is strong site fidelity during parts of the species lifecycle and/or seasonally, and some researchers cite this evidence to justify potential changes to stock units. However, it can be the case that there is considerable mixing of the sub-populations and an appraisal of all of the evidence leads to a conclusion that there is no evidence that a change could lead to better assessment and management advice. In such cases, the risks of realignment of stock boundaries are not warranted.

North Sea herring is one such example where the population is known to consist of several different sub-populations that have discrete well identified spawning areas but the population is managed as a single stock because of the degree of mixing that takes place. However, despite the use of a single stock unit, when the population collapsed in the 1970s the most at-risk spawning area was subsequently protected by limiting fishing effort in that location during the spawning season; i.e. adaptive management measures can be, and are, used to protect sub-stocks even within a single stock unit is the basis for ICES' advice.

Bass is a species where appropriateness of ICES stock units has been queried, so management of this species is specifically described in Section 5.10.2.

5.10.2 Scientific status of the ICES Bass stock unit and the consequent SSB estimate

The ICES stock unit for bass is spatially very large and during consultation with stakeholders the accuracy of this spatial extent has been queried. This section provides a summary of the latest ICES' advice and the aim of current scientific studies.

"Based upon the most up to date science, ICES considers the assessment stock unit for bass as Divisions 4b-c, 7a and 7d-h (central and southern North Sea, Irish Sea, English Channel, Bristol Channel, and Celtic Sea, Figure 4*). Previously, Pawson et al 2007 recommended amended stock units for assessment purposes based upon some UK tagging studies. However, scientific knowledge about bass has advanced since these 2000-2005 studies and ICES continues to recognise the 4b-c, 7a and 7d-h stock unit as the most appropriate for bass stock assessment purposes based upon all of the available scientific evidence.*

ICES recognises that there are probably separate bass sub populations based upon preferred residence areas at certain life stages and seasons in different areas (e.g. North Sea, Irish Sea) but studies have shown that because of a high degree of intermixing these 'sub populations' have the same stock dynamics which would not be the case if the fish were from separate stock units. The stock identity for bass is under regular review and was last assessed by ICES working group scientists in 2018 when it was concluded that the current stock unit continued to be appropriate for assessing the sustainability of the bass stock.

Scientific studies on bass stock identity including tagging programs, microchemistry and genetics are currently underway that are designed to provide more information on the movements of sea bass and the levels of mixing between stocks. The primary purpose of these studies is to determine whether the Bay of Biscay stock unit is indeed a separate stock or whether it should form part of the 4b-c, 7a and 7d-h stock".
(pers. comm. Lisa Readdy Cefas, UK member of ICES Working Group for the Celtic Seas Ecoregion (WGCSE), 12 February 2020. This working group is responsible for the assessment of sea bass in Divisions 4b-c, 7.a and 7.d-h).

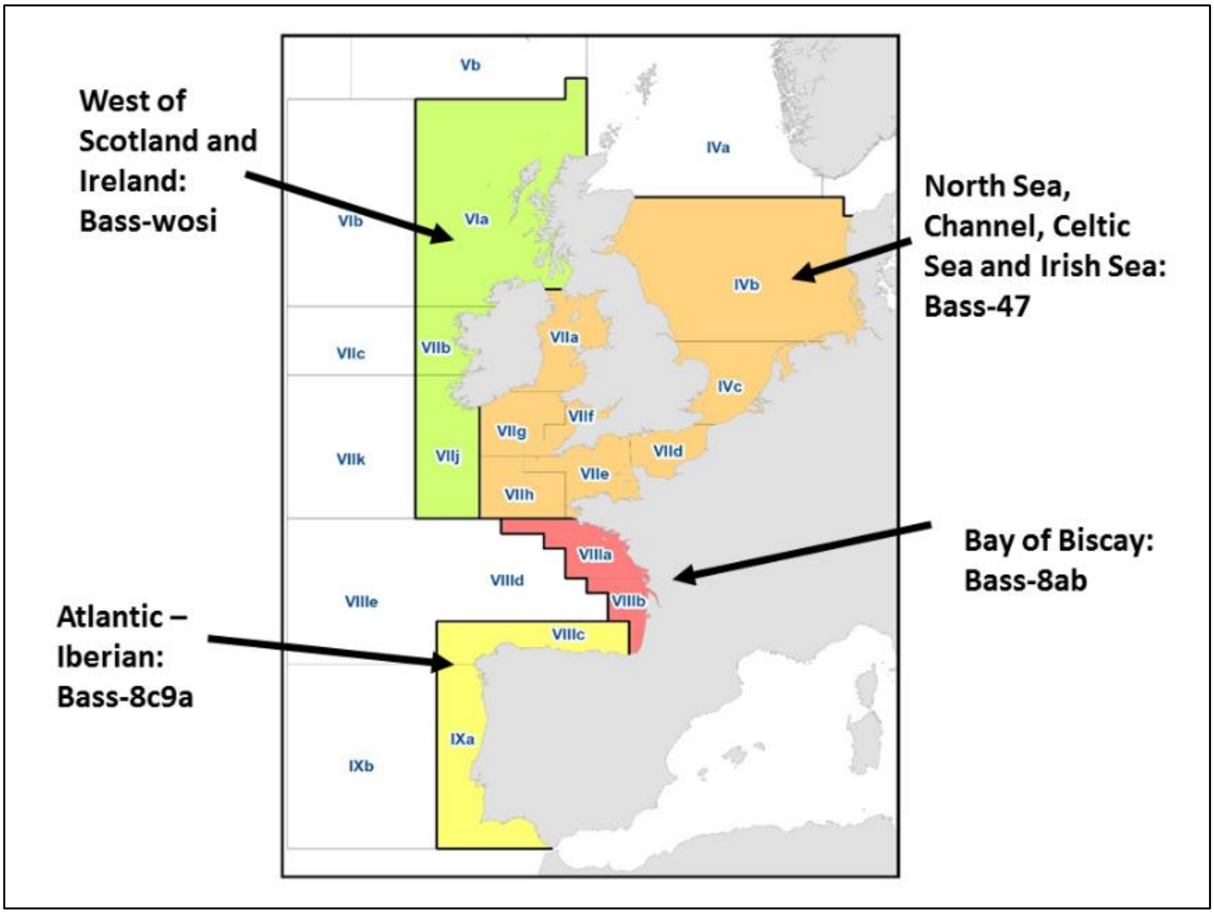

Figure 4 ICES stock units for bass (ICES WGCSE 2019)

In addition to questions about the separateness of the Bay of Biscay bass stock unit, there are similar questions about whether the bass in Irish coastal waters are indeed functionally separate (ICES WGCSE 2019). Stock identity studies are therefore currently focussed on the whether the stock unit size for bass should be expanded and there are no suggestions within ICES of a reduction in the bass stock unit relevant to the Sizewell C assessments.

Finally, after overfishing was identified on the 4.b-c, 7.a and 7.d-h stock bass stock ICES recommended a series of technical measures to reduce fishing mortality and to recover the size of the bass spawning stock biomass. These were implemented under the EU Common Fisheries Policy and the evidence to date is that the stock has partially recovered as predicted by the stock dynamics modelling that uses the 4.b-c, 7.a and 7.d-h stock identity.

ICES recommendations are science led and use the most up to date evidence available. ICES have recently reviewed the bass stock identities and found no compelling evidence to change the existing definitions. We therefore conclude there is strong confidence in the validity of the ICES’ stock unit used as the basis for the SZC effects assessment on bass.

5.10.3 Conclusions on the validity of ICES stock units

Given the extensive body of ongoing research that supports the ICES’ stock definitions, the questions that must be asked are whether it is appropriate, or proportionate, for EDF Energy to attempt to derive new stock assessment unit boundaries for the assessment of the effects of SZC and would any such new boundaries have any scientific credibility? Specifically, would such an effort add anything to advance the sustainability of fish populations given that the predicted effects of SZC (Table 18) are orders of magnitude below those from commercial fishing which is managed using ICES' stock boundaries? We have concluded that ICES' stock boundaries are compromises but they are based on a mature weighing of the best scientific evidence available and they are relied upon by governments to manage fish populations in the waters of all EU member states. Given the negligible predicted SZC impacts compared to those of fishing, and the precautionary nature of ICES' estimates of SSBs, we can find no justification not to use the ICES' stock definitions to assess SZC effects on fish.

5.10.4 How does ICES deal with non-fishing impacts on stocks?

In general, the ICES' approach to advice on fishing opportunities integrates ecosystem-based management with the objective of achieving maximum sustainable yield (MSY). Many of the models used by ICES to estimate MSY and associated parameters assume that factors not explicitly included in the models either remain constant or vary around an historical long-term average. Marine ecosystems are dynamic and fish stocks *may* change not only in response to the fisheries but in response to anthropogenic impacts and naturogenic effects as a consequence of bird and seal predation.

However, ICES does not include anthropogenic losses due to power stations in its stock assessments of commercially important species as such losses are considered as *de minimis*. This is supported by the predicted losses from SZC which show that the power station losses on fish populations would typically amount to less than 0.1% SSB or recorded international landings. (Pers. comm. Dr. C. O'Brien, Chief fisheries science advisor to Defra and vice President of ICES,18 February 2020).

5.11 Evaluating the effect of SZC impingement losses – Comparison with international landings data

For some species, although ICES collates all available fishery information, there are not enough data to carry out a full analytical assessment. While ICES may assess the status of the stock based on trends (e.g. trends in established surveys) and provide relative estimates of SSB, absolute SSB may not be estimated. In this case, we have compared impingement losses with the international landings for the stock area. However, such a comparison is unrealistically conservative as landings will be less than the stock size. For an unexploited stock, landings will typically be much less than 20% of the adult stock size and even for a heavily exploited stock, landings will rarely exceed 50% of the stock size.

5.12 Evaluating the effect of SZC impingement losses – Other comparative data sources

For other species alternative sources for population sizes, catches or landings were used:

a. Losses of thin-lipped grey mullet *Liza ramada* and were compared against ICES' Official Nominal Catches 2006 – 2017 (ICES, 2019), downloaded from the ICES website.

b. Environment Agency and Defra data were used to source catch data for salmon, sea trout, and eels (Table 8).

c. The silver eel SSB used for assessment purposes was from the Anglian RBD only.

d. For river lampreys, losses were compared against a spawning run size estimate for the Humber catchment made in 2018 by the Hull International Fisheries Institute (supplied by Dr J Masters, Environment Agency).

e. Data on shad are more difficult to source, as they are not part of a directed fishery and they may not be landed commercially in the UK. Some landings, of bycatch, are available in the ICES catch data, but these will substantially underestimate the size of the parent stocks. The twaite shad caught at Sizewell are considered to be part of a wider North Sea population that spawns in the rivers of Europe (predominantly in the Elbe but also in the Weser and the Scheldt) (BEEMS Scientific Position Paper SPP100), and the numbers of individuals impinged at SZC have been compared with abundance estimates from monitoring surveys conducted on the Elbe and the Scheldt.

f. Similarly, some landings data for smelt (*Osmerus eperlanus)* are available, but fishing in the UK for this species is limited by the number of fishing authorisations granted. The smelt caught at Sizewell are considered to be part of a wider North Sea population that spawns in at least the Rivers Elbe and Scheldt (BEEMS Scientific Position Paper SPP100). Numbers of individuals impinged at SZC have been compared with adult abundance estimates from monitoring surveys conducted in the River Elbe alone. The adult smelt stock has therefore been underestimated and the effect of SZC impingement has been overstated in this assessment. An assessment has also been made using relevant UK landings data as the existence of a southern North Sea population has yet to be proven.

g. Sand gobies are an unexploited fish stock and accordingly few abundance data are available. In Cefas Young Fish Surveys of the east and south coasts of England, gobies were the dominant species throughout the survey area, with highest densities recorded in the area from Flamborough to Winterton (region 1), followed by the area between Winterton and North Foreland (region 2), and the lowest densities between North Foreland and Portland Bill (region 3) (Rogers and Millner, 1996). For region 2, estimated densities in September of each year were approximately 41 individuals/1000 m^2, which is comparable with the abundances observed in the June BEEMS offshore survey (BEEMS Technical Report TR345). Population estimates for *Pomatoschistus* spp. in region 2 ranged between 36 – 197 million individuals between 1973 and 1995 (mean = 94.7 million, st. dev = 41.3 million individuals). However, studies on the catching efficiency of 2 m beam trawls showed that the gear is only 46% efficient at catching *Pomatoschistus* spp. over coarse sand (Reiss et al., 2006). Taking the trawl efficiency data, this would suggest that only 46 % of the gobies present in the areas surveyed during the YFS were recorded, leading to an underestimation of their abundance. This would imply that the mean population abundance of 97.4 million individuals should be raised to 205.8 million individuals to account for the *Pomatoschistus* spp. not caught.

A summary of the sources for SSBs, landings, catches or population and an indication of whether analytical assessments exist for each species is given in Table 8.

Table 8 Data sources used to provide information on relevant stock unit, landings and SSB

Species	ICES Working Group	Stock unit	Assessment type	Impingement effect comparator	Reference
Sprat	HAWG	Subarea 4 (North Sea)	Analytical assessment	SSB	ICES, 2018
Herring	HAWG	Subarea 4 & Divisions 3.a & 7.d (North Sea, Skagerrak & Kattegat, Eastern Channel)	Analytical assessment	SSB	ICES, 2018
Whiting	WGNSSK	Subarea 4, Division 7.d (North Sea, Eastern Channel)	Analytical assessment	SSB	ICES, 2018b
Bass	WGCSE	Divisions 4.b-c, 7.a, & 7.d-h (Central & southern N Sea, Irish Sea, English Channel, Bristol Channel & Celtic Sea)	Analytical assessment	SSB	ICES, 2018c
Sand goby	-	Not defined	Not assessed	Population abundance	Rogers and Millner (1996)
Sole	WGNSSK	Subarea 4 (North Sea)	Analytical assessment	SSB	ICES, 2018b
Dab	WGNSSK	Subarea 4 & Division 3.a (North Sea, Skagerrak & Kattegat)	Trends only	Landings	ICES, 2018b
Anchovy	WGHANSA	Given as 'Northerly anchovy'	Not assessed	Landings	ICES, 2018d
Thin-lipped grey mullet	-	Not defined	Not assessed	ICES Landings	ICES, 2019
Flounder	WGNSSK	Subarea 4 & 3.a (North Sea & Skagerrak and Kattegat)	Trends only	Landings	ICES, 2018b
Plaice	WGNSSK	Subarea 4 IV & Subdivision 20 (North Sea & Skagerrak)	Analytical assessment	SSB	ICES, 2018b
Cucumber Smelt	-	Not defined but includes the East Anglian coast and rivers on the European coast from the Elbe to the Scheldt	Estimated adult numbers migrating up river	Elbe populations EA landings & ICES Landings	BEEMS Scientific Position Paper SPP100 EA, 2018, 2017a, 2017b, 2015, 2014, 2013a, 2013b, 2013c; ICES, 2019
Cod	WGNSSK	Subarea 4 & Subdivisions 7.d & 20 (North Sea, Eastern Channel, Skagerrak & Kattegat)	Analytical assessment	SSB	ICES, 2018b
Thornback ray	WGEF	Subarea 4 & Divisions 3.a & 7.d (North Sea, Skagerrak, Kattegat & eastern English Channel)	Trends only	Landings	ICES, 2018e
River lamprey	-	Humber catchment	Estimated run numbers	Numbers converted to weight	EA, 2018, 2017a, 2017b, 2015, 2014, 2013a, 2013b, 2013c
Eel	WGEEL	Anglian River Basin District (RBD)	Biomass estimated	Estimated silver eel biomass	(Defra, 2018, 2015)

Species	ICES Working Group	Stock unit	Assessment type	Impingement effect comparator	Reference
Twaite shad	-	Not defined but includes the River Elbe and Belgian river Scheldt. A separate spawning population on the river Weser has not been included in the assessment.	Estimated adult numbers migrating up river	European populations in the Elbe. ICES Landings	BEEMS Scientific Position Paper SPP100 ICES, 2019
Horse mackerel	WGWIDE	Divisions 3.a, 4.b,c & 7.d (North Sea)	Trends only	Landings	ICES, 2018f
Mackerel	WGWIDE	Subareas 1–8 and 14, & Division 9.a (the Northeast Atlantic & adjacent waters)	Analytical assessment	SSB	ICES, 2018f
Tope	WGEF	North east Atlantic	Not assessed	Landings	ICES, 2018e
Sea trout	-	Not defined	Assessment based on CPUE	EA Catch numbers, UK	EA, 2018, 2017a, 2017b, 2015, 2014, 2013a, 2013b, 2013c
Allis shad	-	Garonne	Analytical assessment	Adult stock in 2009, ICES Landings	BEEMS Scientific Position Paper SPP071/s) ICES, 2019
Sea lamprey	-	Not defined	Not assessed	-	
Salmon	WGNAS	North Atlantic	North Atlantic	EA Catch numbers, UK	EA, 2018, 2017a, 2017b, 2015, 2014, 2013a, 2013b, 2013c

Working group acronyms:
HAWG - Herring Assessment Working Group for the Area South of 62°N
WGNSSK - Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak
WGCSE - Working Group on Celtic Seas Ecoregion
WGHANSA - Working Group on Southern Horse Mackerel, Anchovy and Sardine
WGEF - Working Group on Elasmobranch Fishes
WGEEL - Joint EIFAAC/ICES/GFCM Working Group on Eels
WGWIDE - Working Group on Widely Distributed Stocks
WGNAS - Working Group on North Atlantic Salmon

6 Assessment of the significance of impingement effects

There are no formal UK regulatory guidelines for assessing the significance of fish mortality levels caused by impingement in coastal power stations and therefore any assessment must be based on expert judgment.

For the purposes of this assessment we have adopted two screening thresholds that have been selected such that impingement losses lower than the appropriate threshold will have negligible effects on the year to year sustainability of a fish population. Effects above the appropriate threshold would not necessarily indicate a significant adverse effect but require further investigation to determine whether significant effects were, in fact, present.

The thresholds have been selected based upon internationally accepted scientific practice for the sustainability of fish stocks under anthropogenic pressures:

c. For commercially exploited stocks and conservation species (which includes stocks that are not currently exploited): 1% of the SSB or, as a highly conservative proxy, 1% of international landings of the stock.
d. For unexploited stocks: 10% of the SSB or, as a highly conservative proxy, 10% of international landings of the stock.

In this section, scientific rationale for the selection of these screening thresholds are detailed.

Note that at the time of the HPC DCO the screening test that was applied and accepted for potentially significant environmental effects in the HPC Environmental Statement, shadow HRA and WFD was whether the predicted impingement of any of the assessed species was >1% of the SSB or fishery landings.

6.1 Screening thresholds for negligible effects in context

6.1.1 What is meant by a sustainable fish population?

Fishing is the selective removal (or harvesting) of fish. Impingement is therefore a form of fishing but of lower selectivity and much lower impact magnitude than fishing. Fish populations grow and replace themselves and they are therefore renewable resources. In the absence of harvesting, the population size of a stock does not increase indefinitely and stabilises around a maximum that a given habitat can support (the carrying capacity); i.e. it is under density control. The scientific basis for the sustainable use of a renewable marine resource evolved during the first half of the 20th century and is based upon a fundamental ecological principle of density dependent population regulation. As the abundance of a density regulated population is reduced by harvesting, per capita net production increases (by means of increased rates of growth, survival and reproduction), until the population cannot compensate for additional mortality after which point the productivity of the stock decreases and eventually becomes at risk of collapse. The production generated by this compensation (known as surplus production) can be harvested on a sustainable basis on a year on year basis (Rosenberg et al., 1993). Sustainability can therefore be framed as ensuring a sustainable harvest rate; i.e. where the rate of abstraction is less than or equal to the rate at which the population can regenerate itself. Determination of that rate for different fish stocks has been an internationally coordinated endeavour for more than 70 years and has led to well established stock assessment principles.

For well monitored stocks (data-rich stocks) quantitative stock assessment can be carried out which produces spawning stock biomass reference points below which a stock is either at risk of becoming unsustainable or is in an unsustainable condition, together with limits on the maximum harvest rate.

However, fisheries scientists are frequently required to advise on harvesting rates (also known as exploitation rates) of many data-limited stocks where an alternative precautionary approach is required. Several analytical approaches are applied in such circumstances which are largely determined by the availability and quality of the data. The different approaches are essentially based upon:

a. Limiting fishing mortality (F) to no greater than the natural mortality (M) of the species (determined by the life-history of the species).

b. For stocks where there is a record of fish landings, limiting F to the average fishing mortality (or index of fishing mortality) that did not lead to stock decline.

(Source: Food and Oceans Canada 2001)

[Note: The harvesting rate as a percentage of SSB is given by: $1^{-}e^{-F}$ (where F is fishing mortality) and for many demersal and benthic species in UK latitudes the adult M is in the range of 0.1 to 0.2]

Approach a. above is an internationally adopted management approach:

> *‘Escapement strategies are used to manage short-lived species and exploitation rates of up to 20% are advised by ICES’* (pers. comm. Chief Fisheries Science Advisor to Defra, 2018).
>
> *‘Limiting the exploitation rate to 10-20% of the estimated spawning stock biomass will ensure that fishing does not cause the stock to decline to unsustainable levels’* (Giannini et al., 2010).
>
> *‘…a constant harvest rate of 20% of the spawning population became coastwide management policy …’*. (Hall et al., 1988).

M ranges from approximately 0.1 for some benthic species to >0.5 for some pelagic species at Sizewell (BEEMS Technical Report TR383); i.e. sustainable harvest rates vary with the lowest values being for long-lived, late maturating species. The sustainable harvest rate calculated from approach a. above approximates to but is more precautionary than the maximum sustainable yield and as such is well above the biological reference point where the stock would be at risk of becoming unsustainable. For many unexploited species that occur at UK latitudes, this approach implies a sustainable harvesting rate of 10%-20% for such species. However, this formula is not conservative for very short lived (or tropical species) where the sustainable value of fishing mortality is less than M, typically 0.25 to 0.5 M (Caddy and Csirke, 1983). Gobies are such a short-lived species reproducing within the first year of life. They are a very abundant species that is ubiquitous in European coastal areas to at least a depth of 20 m. The species produces pelagic larvae which are dispersed by tidal currents resulting in a lack of genetic diversity over large geographic areas. Sand gobies have an estimated M of 3.3 (Fishbase) implying a sustainable harvesting rate of greater than 50%.

On a precautionary basis a harvesting rate threshold of 10% SSB is considered appropriate as a screening threshold for potentially significant effects that may affect the sustainability of an unexploited fish stock.

6.1.2 Natural variability of fish stocks

Fish stocks are subject to considerable annual variability due to highly variable levels of recruitment, food availability and predation pressure. Individual populations and ecosystems are resilient to such high levels of variability. Impingement at SZB mirrors the variability of local fish populations as the power station is an efficient sampler with low interspecies bias unlike trawl or other net sampling techniques. As explained in Section 5.3, the discontinuous nature of the SZB impingement dataset meant that it was not possible to produce an estimate of year to year variability directly from data collected on site and instead a statistical model had to be fitted to the data.to derive impingement estimates (Section 5.4).

Some examples of the modelled year to year variability in local fish populations in the period 2009 - 2017 are shown in Table 9. The predicted variability for many species is substantially less than at the Hinkley Point estuarine location (BEEMS Technical Report TR456). This is as expected due to the composition of the fish assemblage at the Sizewell coastal location with substantially smaller numbers of 0 group fish whose numbers show the greatest year to year variability due to changes in annual recruitment.

Given the magnitude of such changes, with a minimum change of 130% and a maximum of 770% in year to year numbers, a <1% change due to impingement is negligible, particularly to predator-prey relationships which are adapted to cope with the much greater natural variability.

Table 9 Modelled year to year variations in SZB impingement numbers (2009-2017)

Species	The largest year-year changes in annual numbers from the Sizewell B CIMP dataset 2009-2017 (shown as the ratio of predicted impingement numbers in adjacent years)
Sprat	1.3
Herring	2.4
Whiting	2.8
Bass	1.9
Sand goby	5.6
Sole	2.1
Dab	7.7
Anchovy	4.1
Thin-lipped grey mullet	5.5
Flounder	1.6
Plaice	1.3
Smelt	1.9
Cod	2.2

6.1.3 Comparison with sustainable levels of harvesting rate for data rich stocks

In Section 6.1.1 the internationally accepted precautionary harvest rate of 10-20% SSB was described for unexploited species where little monitoring data exists. It is useful to consider a 1% negligible effects threshold in the context of sustainable harvest rates for data rich stocks which in many cases are much greater than 20% (see Table 10).

ICES produces estimates of the precautionary levels of fishing mortality beyond which sustainability is at risk (F_{pa}). Examples from ICES stock assessments are shown in Table 10. Set against such numbers, an impingement mortality of less than 1% from SZC is negligible. An additional 1% mortality in addition to the effects of fishing is in the noise for practical stock assessments and in practice such a level of effect is much smaller than that due to the uncertainty in the input parameters which are already assessed on a precautionary basis in the stock assessment.

Table 10 Sustainable fishing mortality values based upon a precautionary management approach for species relevant to Sizewell

Species	Sustainable fishing mortality reference values using precautionary approach (Fpa)	ICES Working Group Report	Coefficient of Variation of the SSB 1998-2017
Herring[†]	26%	HAWG	18%
Whiting[‡]	28%	WGNSSK	12%
Bass[*]	19%	WGCSE	23%
Sole[‡]	36%	WGNSSK	30%
Plaice[‡]	31%	WGNSSK	58%

[†] ICES, 2018a; [‡] ICES, 2018b; [*] ICES, 2018c

This point is further underlined by the actual predictions of total SZC entrapment losses in Table 18 of 0.01%, 0.03%, 0.03%, 0.00% and 0.00% of SSB for herring, whiting, bass, sole and plaice respectively.

6.1.4 An example of where screening thresholds for fish mortality have been applied for major infrastructure projects

A 10% screening threshold has been previously adopted by the Thames Tideway Strategy Group. This group comprised representatives from the Environment Agency, Port of London Authority, Thames Water and others and developed water quality standards for the regulation of dissolved oxygen levels in the Thames Tideway to protect fish from mortality associated with storm discharges through combined sewer outfalls (Turnpenny et al., 2004). The efficacy of different standards was compared using an ecotoxicological model, the Tideway Fish Risk Model (TFRM). The Turnpenny report argued that commercial fishery exploitation rates could be sustainable at >50% SSB, depending on the population dynamics of the species. Based upon the Turnpenny report, the TFRM considered annual mortality rates of up to 10 % to be sustainable for all species not subject to fishing mortality (i.e. the integrity of the population would not be threatened), and up to 30 % for longer-lived species such as seabass and salmon. The 10% value was also considered to be the practical minimum change likely to be detectable through ongoing routine WFD Transitional and Coastal (TrAC) water fish surveys.

The subsequent DCO application for the Thames Tideway Tunnel contained a review of the robustness of assumptions made in the TFRM including the definition of fisheries sustainability used in the model. The results of an independent expert peer review of the fisheries work were also provided (Thames Tideway Tunnel, 2013). The review conclusions were that the TFRM remained fit for purpose.

6.1.5 The appropriateness of a 1% SSB screening threshold for impingement effects

To have a negligible impact on a fish stock the predicted total anthropogenic harvest rate must be less than the value whereby the stock can replace itself on a year to year basis. For unexploited data poor species, a precautionary level of 10%-20% SSB is considered sustainable in international fisheries management practice. ICES advises in the context of current management policy which is to manage all species within sustainable limits by 2020; and policy measures have been recommended to the European Commission, which is responsible for managing marine fisheries in Europe, and are now being implemented in order to meet this objective as soon as possible in relation to the 2020 target.

For species which are heavily exploited by fishing a lower effect threshold for impingement is considered appropriate and 1% negligible effect screening threshold for annual impingement for all species provides a precautionary level which is negligible compared with fishing mortality on exploited stocks and would have no effect on their sustainability. A precautionary level of 1% is much less than the natural variability of any species at Sizewell which the ecosystem is adapted to and hence would have no significant effects on predator prey relationships. The use of a negligible effect threshold of 1% of SSB is, therefore, considered to be precautionary. At the request of stakeholders, the sustainability of this threshold and how it has been applied in the SZC assessment for the critically endangered European Eel stock is discussed in 6.1.6.

For non-exploited stocks a 1% threshold is highly precautionary based on fish population dynamics and any observed decline in stock numbers would be due to other factors well beyond the influence of SZC impingement. For such species a 10% screening threshold has been adopted in this assessment (e.g. for sand goby and thin lipped grey mullet)

6.1.6 Appropriateness of a 1% SSB threshold for the endangered European eel

Recruitment indices for glass eel arriving in continental waters decreased continually from 1980 to a low point in 2011. In 2011 a change occurred, and the recruitment trend has been increasing in the period 2011–2019 with a rate significantly different from zero. The reasons for the decline are uncertain but may include overexploitation, pollution, non-native parasites, diseases, migratory barriers and other habitat loss, mortality during passage through turbines or pumps, and/or oceanic factors affecting migrations. (WGEEL 2019). Whether the continental stock has declined as much as recruitment is unclear but the decline in recruitment was preceded by a decline in landings two or more decades earlier, indicating a decline of the continental stock. (Dekker 2003).

The reasons for the increasing recruitment trend are also unclear but may be linked to a substantial reduction in fishing mortality, some of which has been driven by economics, some by regulatory restriction. Commercial landings of glass eels have reduced by 97% from 2000 t in 1980 to less than 60 t in 2019. Commercial landings of yellow and silver eels have fallen by nearly 90% from 20,000 t in the 1950s to less than 2,700 t currently. Recreational fisheries have also reduced substantially in recent years although slope of the trend is unclear due to under reporting. (WGEEL 2019).

The International Union for the Conservation of Nature (IUCN) has assessed the European eel as ‘critically endangered’ and included it on its Red List in 2009. It renewed this listing in 2014 but recognised that: “*if the recently observed increase in recruitment continues, management actions relating to anthropogenic threats prove effective, and/or there are positive effects of natural influences on the various life stages of this species, a listing of Endangered would be achievable”* and therefore *“strongly recommend an update of the status in five years*.”

To date it has not been possible to determine the size of the eel stock SSB.

The current goal of the European eel management, set by the Eel Regulation (Council Regulation 1100/2007), is to “*reduce anthropogenic mortalities so as to permit with high probability the escapement to the sea of at least 40% of the silver eel biomass relative to the best estimate of escapement that would have existed if no anthropogenic influences had impacted the stock…. (The Eel Management Plans)… shall be prepared with the purpose of achieving this objective in the long term*.”

There are insufficient data to reliably determine the biological reference points used in ICES quantitative stock assessments and the purpose of EMPs is to gradually reduce total anthropogenic mortality to achieve a recovery in the adult stock. Given the 10 to 25 y+ taken for glass eels to reach maturation this will inevitably be a lengthy process. It is not clear that the recent (9 y long) trend in increasing recruitment is the early sign of a recovery or not.

For such a population it is reasonable to ask whether 1% of SSB represents a precautionary no effects threshold for SZC. There is no SSB estimate for the entire stock so the alternative measure would be 1% of landings (of 2700 t) or 27 t. Given the lack of biological reference points and the uncertainty surrounding eel stock dynamics, in this assessment it was not considered that 27 t would be sufficiently precautionary and instead the stance was taken of assessing the station effects against the Anglian RBD silver eel biomass of 78 t. with a 1% of SSB = 0.8 t (section 7.6.4.2). The Anglian RBD silver production is a small percentage of the entire stock SSB (on a crude measure of ratio of commercial landings it may only be 0.5% (13.9 t/ 2700

t) of the entire SSB and therefore 1% of the RBD SSB is a highly precautionary measure that could equate to approximately 0.005% SSB.

In conclusion, the 1% of SSB was retained for eel assessment but to be precautionary the SSB of just the Anglian RBD was used instead of population measures for the entire stock.

7 Impingement predictions for SZC - finfish

7.1 Predicted impingement without embedded mitigation measures

Annual estimates of all species impinged at SZB, and predictions for SZC are given in Appendix B. These are unmitigated values, with no adjustment for the embedded station mitigations or conversion to EAV equivalents. Ninety-one fish and 62 invertebrate taxa were recorded in 2009 – 2017. For fish, the most abundant nine species were sprat, herring, whiting, seabass, sand goby, sole *Solea solea*, dab, anchovy *Engraulis encrasicolus* and thin-lipped grey mullet and these contributed 95 % by number of all impinged fish. For invertebrates, the top six species were ctenophores, brown shrimp, pink shrimp, common prawn, swimming crab *Liocarcinus holsatus* and shrimp *Crangon allmani*. These six species contributed 98.9 % of the total invertebrate abundance, but it should be noted that ctenophores alone contributed 83.7 %.

The predicted unmitigated SZC impingement effects for the 24 key species after adjusting to equivalent adults are given in Table 11. Of the 24 key finfish species only the following 3 species exceeded 1%:

- Seabass (1.3 % of SSB)
- Thin-lipped grey mullet (2.5 % of landings) - as an unexploited stock, a 10% threshold is appropriate
- European eel (1.9 % of the precautionary biomass estimate, Section 6.1.6)

For all other species the predicted impingement losses are < 1 %. (For sea lamprey the predicted impingement of <0.13 fish per year is ecologically negligible and could have no effect on the sustainability of the stock. This species has not been further assessed).

7.2 Predicted SZC impingement with LVSE intake heads fitted

With the fitting of LVSE intake heads (designed to reduce the numbers of fish and other organisms being abstracted), the impingement losses of those species that exceeded 1 % in the absence of mitigation were reduced to (Table 12):

- Seabass (0.5 % of SSB)
- Thin-lipped grey mullet (0.9 % of landings) - as an unexploited stock, a 10% threshold is appropriate
- European eel (0.7 % of the precautionary biomass estimate)

The fitting of the LVSE intake heads alone therefore reduces the impingement losses of seabass, thin-lipped grey mullet and European eel to below the 1 % threshold.

7.3 Predicted SZC impingement with FRR systems fitted

With the inclusion of the FRR alone (designed to increase the survival of more robust species), the impingement losses of those species that exceeded 1 % in the absence of mitigation were reduced to (Table 13):

- Seabass (0.7 % of SSB)
- Thin-lipped grey mullet (1.4 % of landings) - as an unexploited stock, a 10% threshold is appropriate
- European eel (0.4 % of the precautionary biomass estimate)

The fitting of the FRR systems alone therefore reduces the impingement losses of seabass and European eel to below the 1 % threshold.

7.4 Predicted SZC impingement with the effect of the LVSE intake heads and FRR systems fitted

With the combined effect of the intake head design and the inclusion of the FRR, the impingement losses of those species that exceeded the 1 % threshold in the absence of mitigation were reduced to (Table 14):

- Seabass (0.28 % of SSB)
- Thin-lipped grey mullet (0.52 % of landings) - as an unexploited stock, a 10% threshold is appropriate
- European eel (0.15 % of the precautionary biomass estimate)

All steps in the mitigation process, including the lower and upper estimates, are given in Appendix C. Given the mitigation of the intake head design and the fitting of the FRR system, no species still exceed the 1 % negligible effects threshold. Further consideration of the predicted SZC effects on conservation species is given in Section 7.6.

7.5 Further consideration of impingement effects on bass and thin-lipped grey mullet

Bass

As described in Section 5 of this report, 20 times more bass were found inshore of the Sizewell-Dunwich Bank in the vicinity of the SZB thermal plume than offshore of the Bank. When SZC begins operation, it will generate a thermal plume but in the deeper water at the SZC outfalls there will be negligible warming at the seabed and the thermal plume effects will be limited to the top 1 m of the sea surface. The SZC plume will have the effect of further warming the inshore waters inshore of the Bank. Bass is a demersal species, but it is known to feed at the surface at night and so could be attracted to the SZC surface plume at night. However, at the surface bass would be invulnerable to the impact of SZC abstraction by the seabed mounted intakes. At depth the water inshore of the Bank would be appreciably warmer than at SZC and there is no reason to consider that the distribution of bass would materially change from what it is now. Making a precautionary assessment that 90% of bass would remain inshore of the Bank (rather than the measure 95%) the expected bass impingement at SZC is 0.028% SSB and not the 0.28% SSB described in Section 7.4.

Thin lipped grey mullet

There is not a directed commercial fishery for grey mullet in the southern North Sea and therefore the landings data (120 t) will substantially underestimate the SSB. The mean length in the commercial catch has been estimated to be in the range 36 to 42cm. At this size the natural mortality is in the range of 0.5 to 0.4 (BEEMS Technical Report TR383) and the calculated sustainable harvesting rate is approximately 33% - 39% SSB (Section 6.1.1). Mullet impingement numbers at SZB show no trend over the period 2009-2017 and provide no evidence that fishing on the stock is unsustainable. It is therefore considered unlikely that mortality on the stock is 33%+ in the southern North Sea and instead a conservative assumption has been made that landings represent 20% of SSB. Using this figure, the predicted impingement in Section 7.4 at 0.5 % of landings is equivalent to approximately 0.1% SSB i.e. below the screening threshold of 1 % of SSB. For such a species without a directed fishery, the use of a 1% threshold is itself overly precautionary and a 10%

threshold is indicated by internationally accepted fisheries assessment methodology (Section 6.1), further reducing the significance of the predicted impingement effect.

The effects of these two changes on the predicted SZC impingement assessment with LVSE intakes and FRR systems fitted is shown in

Table 15.

Table 11 Annual mean SZC impingement predictions with no impingement mitigation. Losses have been converted to adult equivalent (EAV) numbers and weights (t) and calculated as a % of either the mean stock SSB (t) or mean international landings (t). Species where the impingement weight > 1 % of the relevant stock comparator (either SSB or landings – given in bold) are shaded red. Numbers in red font are estimates of the population numbers (e.g. sand goby, smelt, twaite shad, allis shad) or catch numbers (salmon & sea trout)

Species	**Mean SZC prediction**	**EAV number**	**EAV weight (t)**	**Mean SSB**	**% of SSB**	**Mean landings (t)**	**% of landings**
Sprat	7,125,393	5,352,978	56.23	220,757	**0.03**	151,322	0.04
Herring	2,555,783	1,827,944	344.87	2,198,449	**0.02**	400,244	0.09
Whiting	1,865,492	664,261	189.86	151,881	**0.13**	17,570	1.08
Bass	575,367	128,861	197.26	14,897	**1.32**	3,051	6.47
Sand goby	381,612	381,612	0.73	205,882,353	**0.19**	NA	NA
Sole	250,059	53,233	11.40	43,770	**0.03**	12,800	0.09
Dab	148,921	66,211	2.70	NA	NA	6,135	**0.04**
Anchovy	73,865	71,952	1.49	NA	NA	1,625	**0.09**
Thin-lipped grey mullet	67,684	5,642	2.93	NA	NA	120	**2.45**
Flounder	38,180	17,631	1.44	NA	NA	2,309	**0.06**
Plaice	25,288	8,734	2.15	690,912	**0.00**	80,367	0.00
Smelt	23,863	18,170	0.30	105,733,825	**0.02**	8	3.56
Cod	16,845	6,049	15.74	103,025	**0.02**	34,701	0.05
Thornback ray	10,802	2,082	6.65	NA	NA	1,573	**0.42**
River lamprey	6,720	6,720	0.53	62	**0.86**	1	47.65
Eel	4,516	4,516	1.49	79	**1.89**	14	10.70
Twaite shad	3,601	3,601	1.13	7,519,986	**0.05**	1	84.60
Horse mackerel	4,077	4,077	0.57	NA	NA	20,798	**0.00**
Mackerel	628	628	0.20	3,888,854	**0.00**	1,026,828	0.00
Tope	64	64	0.44	NA	NA	498	**0.09**
Sea trout	10	10	0.02	NA	NA	39,795	**0.02**
Allis shad	5	5	0.00	27,397	**0.018**	0	1.79
Sea lamprey[1]	5	5	0.01	NA	NA	NA	NA
Salmon	0	0	0.00	NA	NA	38,456	**0.00**

Table 12 Annual mean SZC impingement predictions considering the effect of the intake head design. Losses have been converted to adult equivalent (EAV) numbers and weights (t) and calculated as a % of either the mean stock SSB (t) or mean international landings (t). Species where the impingement weight > 1 % of the relevant stock comparator (either SSB or landings – given in bold) are shaded red. Numbers in red font are estimates of the population numbers (e.g. sand goby, smelt, twaite shad, allis shad) or reported catch numbers (salmon & sea trout)

Species	**Mean SZC prediction**	**SZC prediction (adjusted)**	**EAV number**	**EAV weight (t)**	**Mean SSB**	**% of SSB**	**Mean landings (t)**	**% of landings**
Sprat	7,125,393	2,729,025	2,050,190	21.53	220,757	**0.01**	151,322	0.01
Herring	2,555,783	978,865	700,103	132.08	2,198,449	**0.01**	400,244	0.03
Whiting	1,865,492	714,484	254,412	72.72	151,881	**0.05**	17,570	0.41
Bass	575,367	220,366	49,354	75.55	14,897	**0.51**	3,051	2.48
Sand goby	381,612	146,157	146,157	0.28	205,882,353	**0.07**	NA	NA
Sole	250,059	95,773	20,388	4.36	43,770	**0.01**	12,800	0.03
Dab	148,921	57,037	25,359	1.03	NA	NA	6,135	**0.02**
Anchovy	73,865	28,290	27,558	0.57	NA	NA	1,625	**0.04**
Thin-lipped grey mullet	67,684	25,923	2,161	1.12	NA	NA	120	**0.94**
Flounder	38,180	14,623	6,753	0.55	NA	NA	2,309	**0.02**
Plaice	25,288	9,685	3,345	0.82	690,912	**0.00**	80,367	0.00
Smelt	23,863	9,139	6,959	0.12	105,733,825	**0.01**	8	1.36
Cod	16,845	6,451	2,317	6.03	103,025	**0.01**	34,701	0.02
Thornback ray	10,802	4,137	797	2.55	NA	NA	1,573	**0.16**
River lamprey	6,720	2,574	2,574	0.20	62	**0.33**	1	18.25
Eel	4,516	1,730	1,730	0.57	79	**0.72**	14	4.10
Twaite shad	3,601	1,379	1,379	0.43	7,519,986	**0.02**	1	32.40
Horse mackerel	4,077	1,561	1,561	0.22	NA	NA	20,798	**0.00**
Mackerel	628	241	241	0.08	3,888,854	**0.00**	1,026,828	0.00
Tope	64	24	24	0.17	NA	NA	498	**0.03**
Sea trout	10	4	4	0.01	NA	NA	39,795	**0.01**
Allis shad	5	2	2	0.00	27,397	**0.01**	0	0.68
Sea lamprey	5	2	2	0.00	NA	NA	NA	NA
Salmon	0	0	0	0.00	NA	NA	38,456	**0.00**

Table 13 Annual mean SZC impingement predictions with FRR systems fitted (no adjustment for the intake head design). Losses have been converted to adult equivalent (EAV) numbers and weights (t) and calculated as a % of either the mean stock SSB (t) or mean international landings (t). Species where the impingement weight > 1 % of the relevant stock comparator (either SSB or landings – given in bold) are shaded red. Numbers in red font are estimates of the population numbers (e.g. sand goby, smelt, twaite shad, allis shad) or reported catch numbers (salmon & sea trout)

Species	**SZC prediction**	**FRR mortality**	**EAV number**	**EAV weight (t)**	**mean SSB**	**% of SSB**	**Mean landings (t)**	**% of landings**
Sprat	7,125,393	7,125,393	5,352,978	56.23	220,757	**0.03**	151,322	0.04
Herring	2,555,783	2,555,783	1,827,944	344.87	2,198,449	**0.02**	400,244	0.09
Whiting	1,865,492	1,026,879	365,649	104.51	151,881	**0.07**	17,570	0.59
Bass	575,367	316,778	70,946	108.61	14,897	**0.73**	3,051	3.56
Sand goby	381,612	78,612	78,612	0.15	205,882,353	**0.04**	NA	NA
Sole	250,059	51,512	10,966	2.35	43,770	**0.01**	12,800	0.02
Dab	148,921	80,196	35,656	1.46	NA	NA	6,135	**0.02**
Anchovy	73,865	73,865	71,952	1.49	NA	NA	1,625	**0.09**
Thin-lipped grey mullet	67,684	37,266	3,106	1.62	NA	NA	120	**1.35**
Flounder	38,180	8,816	4,071	0.33	NA	NA	2,309	**0.01**
Plaice	25,288	5,209	1,799	0.44	690,912	**0.00**	80,367	0.00
Smelt	23,863	23,863	18,170	0.30	105,733,825	**0.02**	8	3.56
Cod	16,845	10,142	3,642	9.48	103,025	**0.01**	34,701	0.03
Thornback ray	10,802	2,225	429	1.37	NA	NA	1,573	**0.09**
River lamprey	6,720	1,384	1,384	0.11	62	**0.18**	1	9.82
Eel	4,516	930	930	0.31	79	**0.39**	14	2.20
Twaite shad	3,601	3,601	3,601	1.13	7,519,986	**0.05**	1	84.60
Horse mackerel	4,077	4,077	4,077	0.57	NA	NA	20,798	**0.00**
Mackerel	628	628	628	0.20	3,888,854	**0.00**	1,026,828	0.00
Tope	64	13	13	0.09	NA	NA	498	**0.02**
Sea trout	10	10	10	0.02	NA	NA	39,795	**0.02**
Allis shad	5	5	5	0.00	27,397	**0.02**	0	1.79
Sea lamprey[1]	5	1	1	0.00	NA	NA	NA	NA
Salmon	0	0	0	0.00	NA	NA	38,456	**0.00**

Note 1: Sea lamprey impingement is predicted to be ecologically negligible and would have no effect on the sustainability of the stock (Section 2.1.1)

Table 14 Annual mean SZC impingement predictions considering the effect of the intake head design and with FRR systems fitted. Losses have been converted to adult equivalent (EAV) numbers and weights (t) and calculated as a % of either the mean stock SSB (t) or mean international landings (t). Species where the impingement weight > 1 % of the relevant stock comparator (either SSB or landings – given in bold) are shaded red. Numbers in red font are either estimates of the population numbers (e.g. sand goby, smelt, twaite shad, allis shad) or reported catch numbers (salmon & sea trout)

Species	Mean SZC prediction	SZC prediction after intake head adjustment	FRR mortality	EAV number	EAV weight (t)	mean SSB	% of SSB	Mean landings (t)	% of landings
Sprat	7,125,393	2,729,025	2,729,025	2,050,190	21.53	220,757	**0.01**	151,322	0.01
Herring	2,555,783	978,865	978,865	700,103	132.08	2,198,449	**0.01**	400,244	0.03
Whiting	1,865,492	714,484	393,295	140,044	40.03	151,881	**0.03**	17,570	0.23
Bass	575,367	220,366	121,326	27,172	41.60	14,897	**0.28**	3,051	1.36
Sand goby	381,612	146,157	30,108	30,108	0.06	205,882,353	**0.01**	NA	NA
Sole	250,059	95,773	19,729	4,200	0.90	43,770	**0.00**	12,800	0.01
Dab	148,921	57,037	30,715	13,656	0.56	NA	NA	6,135	**0.01**
Anchovy	73,865	28,290	28,290	27,558	0.57	NA	NA	1,625	**0.04**
Thin-lipped grey mullet	67,684	25,923	14,273	1,190	0.62	NA	NA	120	**0.52**
Flounder	38,180	14,623	3,377	1,559	0.13	NA	NA	2,309	**0.01**
Plaice	25,288	9,685	1,995	689	0.17	690,912	**0.00**	80,367	0.00
Smelt	23,863	9,139	9,139	6,959	0.12	105,733,825	**0.01**	8	1.36
Cod	16,845	6,451	3,884	1,395	3.63	103,025	**0.00**	34,701	0.01
Thornback ray	10,802	4,137	852	164	0.52	NA	NA	1,573	**0.03**
River lamprey	6,720	2,574	530	530	0.04	62	**0.07**	1	3.76
Eel	4,516	1,730	356	356	0.12	79	**0.15**	14	0.84
Twaite shad	3,601	1,379	1,379	1,379	0.43	7,519,986	**0.02**	1	32.40
Horse mackerel	4,077	1,561	1,561	1,561	0.22	NA	NA	20,798	**0.00**
Mackerel	628	241	241	241	0.08	3,888,854	**0.00**	1,026,828	0.00
Tope	64	24	5	5	0.03	NA	NA	498	**0.01**
Sea trout	10	4	4	4	0.01	NA	NA	39,795	**0.01**
Allis shad	5	2	2	2	0.00	27,397	**0.01**	0	0.68
Sea lamprey	5	2	0	0	0.00	NA	NA	NA	NA
Salmon	0	0	0	0	0.00	NA	NA	38,456	**0.00**

Table 15 Annual mean SZC impingement predictions considering the effect of the LVSE intake heads and FRR systems fitted and the corrections to thin lipped grey mullet and bass assessment detailed in Section 7.5. Losses have been converted to adult equivalent (EAV) numbers and weights (t) and calculated as a % of either the mean stock SSB (t) or mean international landings (t). Numbers in red font are either estimates of the population numbers (e.g. sand goby, smelt, twaite shad, allis shad) or reported catch numbers (salmon & sea trout)

Species	Mean SZC prediction	SZC prediction after intake head adjustment	FRR mortality	EAV number	EAV weight (t)	mean SSB	% of SSB	Mean landings (t)	% of landings
Sprat	7,125,393	2,729,025	2,729,025	2,050,190	21.53	220,757	**0.01**	151,322	0.01
Herring	2,555,783	978,865	978,865	700,103	132.08	2,198,449	**0.01**	400,244	0.03
Whiting	1,865,492	714,484	393,295	140,044	40.03	151,881	**0.03**	17,570	0.23
Bass	57,537	22,037	12,133	2,717	4.16	14,897	**0.03**	3,051	0.14
Sand goby	381,612	146,157	30,108	30,108	0.06	205,882,353	**0.01**	NA	NA
Sole	250,059	95,773	19,729	4,200	0.90	43,770	**0.00**	12,800	0.01
Dab	148,921	57,037	30,715	13,656	0.56	NA	NA	6,135	**0.01**
Anchovy	73,865	28,290	28,290	27,558	0.57	NA	NA	1,625	**0.04**
Thin-lipped grey mullet	67,684	25,923	14,273	1,190	0.62	600	**0.10**	120	0.52
Flounder	38,180	14,623	3,377	1,559	0.13	NA	NA	2,309	**0.01**
Plaice	25,288	9,685	1,995	689	0.17	690,912	**0.00**	80,367	0.00
Smelt	23,863	9,139	9,139	6,959	0.12	105,733,825	**0.01**	8	1.36
Cod	16,845	6,451	3,884	1,395	3.63	103,025	**0.00**	34,701	0.01
Thornback ray	10,802	4,137	852	164	0.52	NA	NA	1,573	**0.03**
River lamprey	6,720	2,574	530	530	0.04	62	**0.07**	1	3.76
Eel	4,516	1,730	356	356	0.12	79	**0.15**	14	0.84
Twaite shad	3,601	1,379	1,379	1,379	0.43	7,519,986	**0.02**	1	32.40
Horse mackerel	4,077	1,561	1,561	1,561	0.22	NA	NA	20,798	**0.00**
Mackerel	628	241	241	241	0.08	3,888,854	**0.00**	1,026,828	0.00
Tope	64	24	5	5	0.03	NA	NA	498	**0.01**
Sea trout	10	4	4	4	0.01	NA	NA	39,795	**0.01**
Allis shad	5	2	2	2	0.00	27,397	**0.01**	0	0.68
Sea lamprey	5	2	0	0	0.00	NA	NA	NA	NA
Salmon	0	0	0	0	0.00	NA	NA	38,456	**0.00**

7.6 Consideration of the impingement losses of finfish species of conservation concern

7.6.1 Cucumber Smelt

Smelt (*Osmerus eperlanus*) are found in coastal waters and estuaries around the western coast of Europe, from southern Norway to north-west Spain (Maitland, 2003a). Although there are several non-migratory populations in large freshwater lakes in Scandinavia, it is usually found in coastal waters and migrates into large clean rivers to spawn (Wheeler, 1969). Adults live in the marine environment, but migrate to estuarine or slightly brackish rivers in early spring (February to April) to spawn, after which the adults return to sea (Maitland, 2003a). Smelt shed their adhesive eggs onto the river bed in the brackish reaches of tidal rivers during March and April, where they hatch in about 3−4 weeks. Spawning appears to be determined by temperature and tides. In the River Thames, spawning takes place in the Wandsworth area of the estuary and 0+ fish first appear at 18mm at Greenwich in mid-May (Colclough et al., 2002).

The smelt was once common in Great Britain and supported commercial fisheries in the estuaries of most large rivers from the Clyde and Tay south. Maitland (2003a) reports that fisheries for smelt existed in the tidal reaches of all the Broads rivers in Norfolk until at least 2002; commercial fisheries ‘yielding 3 to 6 t’ per annum were still active in the River Waveney in 1991; smelt are occasionally taken in herring nets in the Orwell Estuary; and commercial fishermen were taking large catches – 190−250 kg per day in the Medway and the River Thames by 2002. Today, smelt occur in at least 36 water courses in England and Wales, with large populations in the rivers Thames, Humber and Dee, the Wash and Great Ouse, as well as in water courses of the Norfolk Broads. Smaller populations exist in the rivers Alde/Ore, Ribble and Conwy, and recovery of supposed extinct populations seems to be underway in the rivers Tyne and Mersey (Colclough and Coates, 2013).

There are commercial fisheries for smelt in the Rivers Waveney, Bure and Yare, predominantly for angling baits, although smelt are now sold to restaurants (Dr. A. Moore, Cefas, pers. comm.) and since 2011 there has been a requirement for commercial smelt fisheries to be authorised by the EA and to make annual catch returns. The annual catch of smelt in 2014 was 11,006 kg from 4 licence holders (EA, 2015). However, the report does not state the rivers that the licence holders exploited, but it is known that they are based in the Ouse (Yorkshire and Cambridge), Waveney/Yare and Thames (Dr. A. Moore, Cefas, pers. comm.).

Smelt are found all along the Anglian coast, in the southern North Sea and on the European coast from the Channel to Denmark but there is no targeted fishery at sea. The nearest estuary to Sizewell with a known smelt population is the Alde/Ore, approximately 25 km to the south of Sizewell. Other than that, the nearest estuary to Sizewell is the Blyth at approximately 12 km to the north of Sizewell. Adult smelt have been sampled in the Blyth but there is no evidence of a breeding population. Surveying in April and May 2016 found no evidence of suitable spawning habitat, a barrier to upstream migration, no eggs nor any smelt in spawning condition at the time that other Anglian rivers contained spawning aggregations (BEEMS Technical Report TR382). This work concluded that it was highly unlikely that there was a spawning population in the Blyth primarily due to a lack of suitable spawning habitat and the presence of a barrier to up river migration.

Information on smelt stocks is limited. Colclough and Coates (2013) concluded that the smelt found in the Wash are probably from a common stock which may access some or all of the tributaries that flow into the Wash, and Maitland (2003a) reported that it is likely that stocks in Suffolk belonged to a population associated with the Norfolk Broads and the estuarine and brackish waters around Great Yarmouth and Lowestoft. More recent genetic analysis of 215 smelt collected from the SZB CIMP programme and from the Thames, Waveney, Great Ouse and Tamar estuaries showed that East Anglian smelt are genetically homogeneous with no genetic structuring seen within the region. Smelt from the Tamar was clearly distinct from the East Anglian collections (BEEMS Technical Report TR423).

Given the genetic information on the smelt at Sizewell, it is probable that the smelt impinged are from multiple locations on the east coast of the UK and, based on the comparable distances, from European estuaries of at least the Scheldt (Belgium) and the Elbe in Germany (this hypothesis is considered reasonable but it is recognised that it has not yet been proven). Considering only UK populations and given the limited number of licences issued for commercial exploitation, the size of fishery landings will be a substantial underestimate of the stock size. Comparisons have therefore been made against estimates of population size for the River Elbe (Data on the abundant Scheldt population could not reliably be extracted form the available publications and would require clarifications from the Belgian authorities before their data could be used in the SZC assessment). Between 2009 and 2017, an estimated annual average 105.7 million adult smelt passed through the River Elbe (BEEMS Scientific Position Paper SPP100). In the absence of mitigation, the losses of smelt by SZC represent 0.02 % of these population numbers; with consideration of the LVSE intake head design losses fall to 0.01 % of the population.

Smelt abundance at Sizewell as indicated by the SZB impingement data has no trend from 2009 to 2017 and has apparently not changed since 1981/82 (Section 9.1). Losses due to commercial fishing in the 35+ year period has not had any discernible effect on smelt numbers at Sizewell and fishing mortality must therefore have been low with SSB being much greater than UK landings. If the possibility of smelt at Sizewell being part of a southern North Sea population embracing Belgian and German sub populations is ignored, assessment of SZC entrapment effects would have to be based upon UK landings data. On a conservative basis the maximum sustainable harvesting rate on an ‘Anglian’ smelt stock would be 16% (using the precautionary assumptions in Section 6.1.1 for calculating the sustainable harvesting rate for short lived species (i.e. the use of natural mortality/4) and an assumed natural mortality of 1.0 for 100% mature 2-year old fish, BEEMS Technical Report TR383). Given the stability of the Sizewell population as indicated by impingement numbers, fishing and other anthropogenic mortality is most likely less than 16% SSB and SSB will therefore be 6.25 times UK landings, possibly more given the very restrictive licensing policy operating in the UK (e.g. with only 4 licences issued in 2015). I,e. the indicated effect level of SZC entrapment in Table 18 of 1.36% of landings would equate to 0.22% SSB and be assessed as negligible.

7.6.2 River lamprey and sea lamprey

The river lamprey (*Lampetra fluviatilis*) is found in coastal waters, estuaries and accessible rivers in western Europe, from southern Norway to the western Mediterranean. It is widespread in catchments throughout the UK, except in northwest Scotland and in industrial areas where water quality is poor or where obstacles prevent the upstream migration of adults prior to spawning (Maitland, 1972). The rivers of the Severn Estuary are thought to be the most important area in the UK for sea lamprey and possibly river lamprey too (Bird, 2008).

The biology and ecology of lampreys have been described in detail and reviewed by Maitland (2003b). Both sea and river lampreys spawn in coarse, well aerated river beds and juveniles, known as ammocoetes, spend several years living in aerobic silt beds filtering sediments, before transforming to migrants that move downstream to sea in the spring. After some years growing in the marine environment they move back into freshwater, migrate upstream to spawn. River lamprey move into freshwater during the previous summer, winter and spring before spawning in spring, whereas sea lamprey migrate into estuaries in the spring and then upriver to spawn in late spring to early summer (Hardisty, 1986). The fish are semelparous and die after spawning (Larsen, 1980).

Genetic studies suggest that sea lamprey (*Petromyzon marinus*) are a single, pan-European population (Almada et al., 2008) with widespread distribution. This is thought to be determined to a large extent by the movements of the fish hosts on which the lampreys feed and the fact that the adult lamprey do not display any apparent homing behaviour during spawning migrations (Berstedt and Seelye, 1995). River lamprey also display the same parasitic behaviour in the marine environment and are also not considered to home to natal rivers. As would be expected they show only low levels of genetic differentiation between local stocks across England. (Bracken et al., 2015).

Fisheries for river lamprey exist in the Netherlands, Sweden, Finland, Estonia and in the UK. Sea and river lampreys are qualifying features of the Humber SAC. River lamprey are a primary reason for selecting the Derwent SAC, with sea lamprey a qualifying feature.

Despite a historical long-term decline in status, the distribution of river lamprey in waters of England and Wales appears to have increased in recent years, coincident with increased water quality in UK and European rivers. However, recording effort has also increased and JNCC, 2013 considered that it remained unclear whether the apparent increase in range is a consequence of increased levels of reporting or a true change in status. Results from impingement measurements at Sizewell showed no river lamprey caught in the years1981/82 at SZA but an estimated annual mean of 2624 caught at SZB (Section 9.1). At Sizewell there has, therefore, been a substantial increase in river lamprey population sometime in the period 1982 to 2009. This is mirrored in multinational North Sea ecoregion monitoring surveys which found an almost complete absence of lampreys from 1977 to 1992 followed by a substantial increase in numbers thereafter. (Heesen *et al* 2015).

Historically, commercial fisheries for river lamprey have taken place in several large rivers, including the Severn and Yorkshire Ouse. The Ouse bait fishery was re-established in 1995, with annual catches around 4000 kg (Masters et al., 2006) which was estimated to have amounted to approximately 20% of the Ouse population but without showing any evidence of population decline. Since 2013, the Environment Agency has controlled the fishery by means of authorisations: 4 for 2015 and 2016 (EA, 2017a, 2017b). This fishery is subject to a catch limit (JNCC, 2013), and an overall agreed anthropogenic loss limit for river lampreys of 5 % of the population size estimated from mark-recapture experiments carried out in 2003 (Masters et al., 2006). There is also a limit on the season (open: 1 November to 10 December). Total allowable catch (TAC) has varied over the years and is often different for various rivers of the Humber catchment (Dr J Masters, Environment Agency, pers. Comm.). In 2017 and 2018 fishing was allowed on a non-consumptive basis only (catch and release), but for 2019 a quota of 898 kg has been set for the Humber catchment.

In 2018, the Hull International Fisheries Institute (HIFI) undertook mark-recapture experiments of lampreys in the commercial fishery at Naburn, the River Ouse. Almost 1,500 lampreys were marked with PIT tags were used to estimate the run size of the lamprey population in the Humber catchment. Work was carried out during the fishing season only, but lampreys can migrate between October and February, so the estimated run size is likely an underestimation of the total spawning run. The Environment Agency used the HIFI data to create a population estimate for the Humber catchment of 783,043 individuals, equating to 61.86 t.

SZC with the proposed intake head design and FRR mitigation is predicted to take 530 individuals or 0.04 t of river lampreys, which equates to 0.07 % of the estimated 2018 lamprey run in the Humber catchment. The Southern North Sea population of river lamprey are probably one stock with spawning taking place in the Ouse in the UK but also in the Scheldt in the Netherlands where the adult population is estimated to be in the 100,000s (Jansen et al., 2007) and in other European rivers that drain into the North Sea (e.g. rivers Eider, Elbe, Weser and Ems). The SZC predicted impact on the river lamprey population is, therefore, considered negligible.

For sea lampreys, the estimated annual impingement loss with the FRR mitigation is < 0.13 fish, with a maximum of 2 individuals. This is considered negligible for a stock that is widespread throughout the N. Sea.

7.6.3 Twaite shad and allis shad

Allis shad (*Alosa alosa*) and twaite shad (*Alosa fallax*) both belong to the herring family and historically had a broad distribution along the Northeast Atlantic coast. Both species are anadromous; adults spend most of their lives in the marine environment but migrate through estuaries to spawn in freshwater. Populations of both species have declined, their distribution has diminished, and they are both classified as species of conservation concern. Both are listed in Appendix III of the Bern Convention and Annexes II and V of the Habitats Directive.

Alosa alosa was historically distributed along the eastern Atlantic seaboard from Norway to North Africa and in the western Mediterranean. It has declined significantly throughout its range and is now extinct in several former areas. Currently, populations of *A. alosa* exist along the north-eastern Atlantic coasts in some large rivers of France (Loire, Gironde–Garonne–Dordogne, and Adour) and Portugal (Minho and Lima) (BEEMS Scientific Position Paper SPP071/s). There are currently no known spawning sites for this species in the

United Kingdom, and only two locations in the UK where individuals in breeding condition have been recorded: the river Tamar in SW England and the Solway Firth on the border between England and Scotland (Jolly *et al*., 2012). Immature adults are occasionally found in the Bristol Channel, the English Channel and the UK east coast. It is considered probable that British-caught specimens are from the Loire to Gironde populations (BEEMS Scientific Position Paper SPP071/s). *A. alosa* only spawns in any substantial numbers in France and Portugal (the species has recently been reintroduced into the Rhine but the number of recruits is still small). There is no international stock assessment for *A. alosa* but some assessments are performed on specific French watersheds. The Gironde–Garonne–Dordogne basin had a notable commercial fishery at the end of the 20th century. The adult population (age 4+) was estimated to be 710 000, 798 000, and 834 000 in 1994, 1995, and 1996, respectively, with a mean exploitation rate by the commercial fishery of 44%. It was reported that the commercial fishery in that basin caught approximately 500 t annually. However, in the first decade of the 21st century, there was a recruitment collapse probably due to over fishing and a fishery moratorium was imposed in the Gironde estuary from 2008 (BEEMS Scientific Position Paper SPP071/s). The estimated adult stock size in the basin was 27,397 in 2009. The Loire watershed also has a breeding population of *A. alosa* and a small commercial fishery. The count of alosa was 2,557 in 2009 but the video counting system does not cover all the tributaries of the Loire and cannot distinguish between *A. alosa* and *A. fallax*. The counters are located relatively high in the river basin at ranges of 260 – 663km from the sea and are, therefore, probably counting mostly *A. alosa*. It is also known that a substantial amount of spawning takes place downstream of the counters thereby underestimating adult numbers (BEEMS Scientific Position Paper SPP071/s).

A. fallax is distributed along most of the west coast of Europe from the eastern Mediterranean Sea to southern Norway and in the lower reaches of large rivers along these coasts that are accessible to the fish (i.e. rivers that lack barriers to migration). The species has declined substantially across Europe and in the UK; it is now known to breed only in the Severn River Basin District (RBD – in the Severn, the Wye, the Usk and the Tywi) and in the Solway Firth. There are also non-breeding populations in the UK off the southern and eastern coasts, at Looe Bay, Hastings and Sizewell (Jolly et al., 2012). The decline of the *A. fallax* population has not been as severe as that of *A. alosa*, probably because of its ability to use spawning sites closer to the sea than those of *A. alosa*; sites that are not, therefore, subject to the barriers to migration that block *A. alosa* from accessing its traditional spawning sites.

Allis shad are protected under the Wildlife and Countryside Act (1981), and it is illegal to fish for the species in the UK.

Most of the twaite shad reported are taken as bycatch in coastal or estuarine net fisheries or by anglers fishing for other species (although several hundred are usually taken each year by anglers in the River Wye and other rivers into which twaite shad run to spawn).

Shad of both species migrate into rivers and spawn in flowing water over stones and gravel from mid-May to mid-July. Allis shad normally spawn only once, but twaite shad may spawn several times in their lives (Miran Aprahamian, Environment Agency, unpublished).

Young twaite shad remain in estuaries to feed on invertebrates, initially insect larvae and zooplankton and then increasingly on larger crustaceans such as shrimps and mysids and also small fish as they grow, reaching 10–15 cm after one year (Aprahamian, 1989). Water temperature during the months June−August seems to be an important influence in determining year-class strength in 0+ twaite shad.

Little is known about the movements of adult shad along the coast, but they have been studied when they enter estuaries and migrate upstream to spawn in freshwater, in particular in relation to barriers caused by obstacles such as waterfalls or man-made dams and weirs, and pollution (Aprahamian, 1982; Maitland, 1972). Adult shad of both species gather in the estuaries of suitable rivers in April and May, and the upstream migration from the estuary appears to be modified by temperature, with peak migratory activity at 10–14ºC and during relatively high discharge levels (Aprahamian, 1982; Claridge and Gardner, 1978).

On the North Sea coast of Europe adult twaite shad are relatively common from the Belgium to Denmark. Adult populations are increasing in the known German spawning rivers of the Elbe/Weser with sporadic spawning in the Ems (Helcom, 2013; Magath and Thiel, 2013). Twaite shad populations are also increasing in the Baltic, particularly in Poland and Lithuania where the species is classified as in good condition with increasing populations (Helcom, 2013). Genetic analyses of twaite shad from Sizewell demonstrate that they do not originate from the Severn catchment (Jolly et al., 2012). Sabatino and Alexandrino (2012) identified a North Sea twaite shad population with low genetic diversity between fish sampled off Belgium (Scheldt) and Denmark and also the Solway Firth. These analyses identified separation between the Baltic and North Sea populations and the North Sea population would therefore appear to most likely originate from the German rivers of the Elbe/Weser and the Belgian river Scheldt. The twaite shad caught at Sizewell are >1 yr old juveniles to sexually mature adults that are part of widely dispersed feeding population in the North Sea before eventually returning to probably European rivers to reproduce.

Figure 5 shows a map of Natura 2000 sites designated for *A. fallax* in the southern North Sea and eastern Channel (https://eunis.eea.europa.eu/species/Alosa%20fallax downloaded November 2019). There are no known UK east coast spawning sites nor HRA designated sites for the species. European sites designated for the species include the estuarine and coastal areas in which the species either feeds as juveniles or transits on its way to southern North Sea feeding grounds as adults. (For example, the entire German North Sea coast is in one of more designated sites) More materially the designated sites include the European rivers where the species is known from monitoring data to successfully spawn. The Elbe in Germany has largest breeding population with other breeding populations in the Scheldt (Belgium) and sporadically in the Weser (Germany). The other rivers shown in Figure 5 have negligible or no spawning currently.

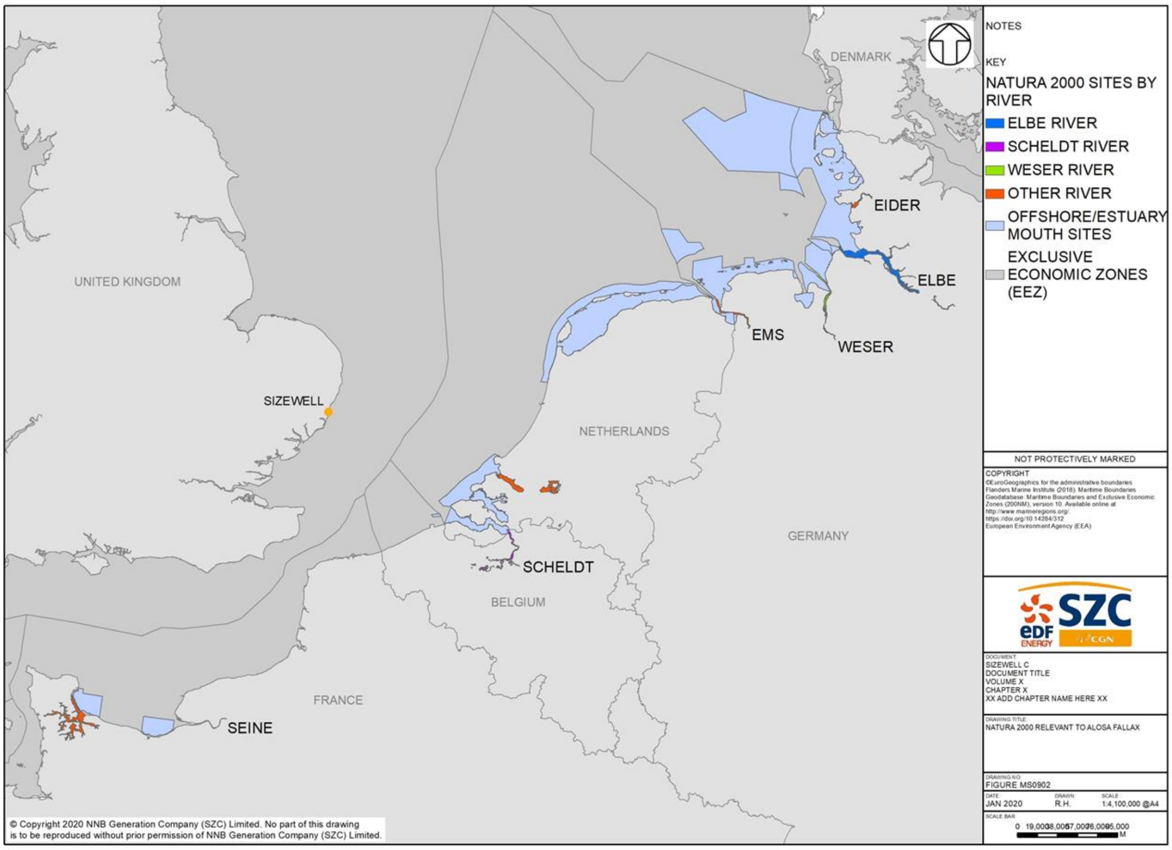

Figure 5 Southern North Sea and Channel Natura 2000 sites designated for Twaite shad

An estimated 3,601 twaite shad will be lost by the proposed SZC station in the absence of any mitigation. This number is reduced to 1,379 individuals with the effect of the LVSE intake heads (FRR mitigation does not increase shad survival as the group is classed as pelagic). There is currently no SSB for the North Sea twaite shad population and no directed fishery, so comparison with landings data does not provide a meaningful assessment. Losses have been compared with the population estimates available from spring monitoring surveys conducted on the Rivers Elbe and Scheldt. Between 2009 and 2017, an average estimated 7.5 million adult twaite shad pass through these two river systems (BEEMS Scientific Position Paper SPP100). In the absence of mitigation, the losses of twaite shad by SZC represent 0.05 % of these population numbers; with consideration of the LVSE intake head design losses fall to 0.02 % of the population. This represents a negligible effect on the species in these 2 river systems which would have no effect on the sustainability of the population. It is therefore considered that there would be no significant transboundary effects on any European site designated for *A. fallax*.

7.6.3.1 Identification of 0 group twaite shad in SZB impingement samples

0 group twaite shad have some similarities with juvenile herring (e.g. the scale pattern is similar) which can make identification difficult and the accuracy of identifying 0 group twaite shad has been queried. For the impingement sampling at SZB a very experienced team of fish taxonomists has been deployed including those who have handled juvenile twaite shad from Hinkley Point (where 0 group fish do occur). Based upon published taxonomic information and the experience with the Hinkley Point samples, we are confident that the sampling team can reliably distinguish twaite shad from other clupeids (based upon a combination of markings, body depth and eye size).

7.6.4 European eel

The European eel (*Anguilla anguilla*) is distributed across the majority of coastal countries in Europe and North Africa, with its southern limit in Mauritania (30°N) and its northern limit situated in the Barents Sea (72°N) and spanning the entire Mediterranean basin (WGEEL 2019).

The European eel life history is complex, being a long-lived semelparous (mature adults die after spawning) and widely dispersed stock. The shared single stock is genetically panmictic and data indicate the spawning area is in the southwestern part of the Sargasso Sea. The newly hatched leptocephalus larvae drift for two to three years with the ocean currents for more than 5000km to the continental shelf of Europe and North Africa, and enter continental waters. There, they metamorphose into the post-larval transparent glass eel. At this stage, glass eels migrate across the continental shelf to the coast. After reaching the coast, glass eels enter estuaries (in the UK Severn starting from about January/February). Glass eels metamorphose into pigmented elvers which either remain and feed in coastal marine or estuarine waters or begin active upstream migration to freshwater. The growth stage, known as yellow eel, may take place in marine, brackish (transitional), or freshwaters. This stage may last typically from two to 25 years (and could exceed 50 years) prior to metamorphosis to the “silver eel” stage and maturation. At this stage silver eels migrate 5000 km+ back to their spawning grounds. Age-at-maturity varies according to temperature (latitude and longitude), ecosystem characteristics, and density-dependent processes. The European eel life cycle is shorter for populations in the southern part of their range compared to the north. Age at maturity ranges from 10 to 20+ years in northern temperate waters (Vøllested, 1992), and is earlier for males than for females. (WGEEL 2019, McCleave 1993, Tesch 2003, Harrison *et al* 2014).

The stock of the European eel is described as being outside safe biological limits, with urgent action required by European Union Member States to assist recovery of the panmictic stock (Harrison *et al* 2014). Historical publications indicate that the decline in stock abundance and/or fishing yield might have started as early as in the 1800s, and might have been related to inadvertent side effects of anthropogenic actions (water management). The downward trend in yield has been acknowledged internationally since the late 1960s, but up to today, it is unclear what processes were causing the decline, which occurred even in times of high recruitment up to 1980 (Dekker and Beaulaton 2015).

7.6.4.1 Eel catch statistics (from WGEEL 2019)

Glass eels

Glass eel fisheries within the EU take place in France, UK, Spain, Portugal and Italy. Glass eel landings have declined sharply from 1980, when landings were larger than 2000 tonnes, to 62.2 t in 2018, 58.6 t in 2019 (provisional figure), and a mean for the previous 5 years (2013–2017) of 56.5 t. The amount of glass eel arriving in continental waters declined dramatically in the early 1980s to a low point in 2011. The reasons for this decline are uncertain but may include commercial overexploitation, pollution, non-native parasites, diseases, migratory barriers and other habitat loss, mortality during passage through turbines or pumps, and/or oceanic factors affecting migrations. Statistical analyses of time-series from 1980–2019 show that there was a change in the trend of glass eel recruitment indices in 2011; the recruitment has stopped decreasing and has been increasing in the period 2011–2019 with a rate statistically significantly different from zero. The highest point during the period from 2011–2019 was in 2014. It is not yet clear whether this change indicates a sustained recovery in eel recruitment.

Yellow and silver eels

Total EU commercial landings of yellow and silver eels were estimated to be around 20,000 t in the 1950s to 2000–3500 t around 2009, most recently being 2393 t in 2017, 2694 t in 2018 (provisional) and a mean of 2729 t for the preceding 5 years (2012–2016).

Recreational catches and landings are poorly reported, and so values must be regarded as minima. Recreational landings for yellow and silver eel combined declined from 543 t for 2016 (from ten EU countries), 195 t for 2017 (eight countries reporting) and 148 t for 2018 (five countries reporting). Overall, the impact of recreational fisheries on the eel stock remains largely unquantified although landings are considered to be at a similar order of magnitude to those of commercial fisheries.

A rough estimate of eel loss to all non-fishery anthropogenic factors (largely hydropower and pumps in rivers) estimated from reported mortality indicators from approximately half of the countries that report eel statistics to the EU is 1625 tonnes annually.

Summarising these statistics, the annual EU anthropogenic impact on the yellow and silver eel stock in 2016 was approximately 4,900 t (comprising 2729 t fishing, 543 t recreational fishing and 1625 t from pumps and hydropower in rivers) compared with approximately more than 22,000 tonnes in the 1950s when commercial fishing accounted for 20,000 tonnes

There is no internationally agreed SSB estimate for the entire eel stock.

7.6.4.2 Local eel population

There was once a considerable fishery for yellow and silver eels in the Anglian River Basin District (RBD), the catchments of rivers that drain to the North Sea along the east coast of England between the Humber and Thames (Defra, 2010). However, eel fishing is now mainly a subsistence activity for the remaining fishers in Suffolk rivers and the adjacent coast, who use fyke nets for yellow eels between March and November and for silver eels from September to December.

Although yellow eel populations in freshwater catchments may be considered as largely separate, there is no evidence that silver eels migrating outwards or inward-recruiting glass eels comprise separate biological entities, i.e. the European eel is a single stock unit (Maes et al., 2006; Palm et al., 2009). ICES (ICES, 2013) demonstrated that the overall recruitment of European glass eels is now <10% of the levels observed in the 1960s and 1970s, but there is no assessment of the whole stock. In 2008 and again in 2013, the European eel was listed in the IUCN Red List as a critically endangered species (Jacoby and Gollock, 2014).

The most comprehensive assessment available for the status of the eel population in East Anglia is provided in the Eel Management Plan (EMP) for the Anglian River Basin District (RBD). Data on yellow eel populations for Essex and Suffolk catchments are derived from electric fishing surveys, carried out as part of the EA's routine monitoring programme. An assessment, based on combined data gathered from 2009 to 2011 and reported to the European Commission in June 2012 as part of the UK's EMP Progress Report, estimated a total output of 62.3 t of silver eels from the Anglian RDB each year (Defra, 2012). Estimates were updated and presented for individual years in 2015 and 2018 (Defra, 2018, 2015).

7.6.4.3 Potential risks of SZC eel entrapment

In principle, the following eel life stages could be at risk from entrapment in SZC:

- Glass eels migrating along the coast from the north or the south to find a suitable estuarine/freshwater habitat;
- yellow eels moving between different river systems along the East Anglian coast or living in coastal waters; and
- silver eels migrating to the Sargasso Sea that after leaving estuaries along the East Anglian coast may transit past Sizewell.

Glass eels

Glass eels enter estuaries all year round, with migration peaks depending on latitude and also the variability of oceanic factors. In southwest Spain, highest densities occur between late autumn and spring with two migration peaks observed, whereas peak glass eel migration in the UK is later, typically occurring from February to May.

Glass eels that contribute to UK populations first arrive in the Western Approaches and then transit with the tidal currents either through the English Channel into the southern North Sea or from the north, following currents that flow around Scotland and southwards into the southern North Sea. The time to reach the southern North Sea is dependent on met-ocean conditions over Northern Europe and the relative strength of the Gulf Stream and associated currents around the British Isles. However, little is known about the residence times of glass eels in the southern North Sea. It is considered that glass eels reach the coast and then seek a salinity or other chemical cue to commence migrations up estuaries and then, for a large proportion of their number, to freshwater. The time spent in the open North Sea will, therefore, be dependent on the tidal currents and when the eels sense estuarine cues. In the journey from the Western Approaches to the southern North Sea the density of glass eels in coastal waters will be reduced progressively and substantially as large proportions of the eels migrate up estuaries encountered on route. In particular, eels travelling through the Channel and then heading north will encounter the very large Thames freshwater signal followed by signals from Essex and Suffolk rivers before they reach the coast in the vicinity of Sizewell. Residual hydrodynamic flows will also tend to carry a proportion of eels passing through the Straits of Dover towards the Dutch Coast. Eels migrating from the north will also encounter freshwater signals at for example the Humber, the Wash, North Norfolk coast rivers and the Broads at Yarmouth. Thereafter residual flows will tend to carry eels towards continental Europe. The net result of these tidal flow patterns is that the expected glass eel density in the vicinity of Sizewell would be expected to be amongst the lowest in the UK.

Given their morphology of typically 4 mm width (and up to 8mm for 130 mm elvers), it is likely that most glass eels will pass through the 10 mm mesh on the SZB and proposed SZC cooling water screens and only rarely appear in impingement samples. In the BEEMS CIMP programme from 2009 to 2017 two glass eels have been sampled; 1 in March 2013 and 1 in January 2017 with both of length of approximately 67.5mm. The BEEMS targeted glass eel surveys in April and May 2015 only detected 1 glass eel in 105 valid tows using a methodology which successfully sampled many glass eels in the Bristol Channel. No glass eels or elvers have been detected in water drawn from the SZB forebay during the 12 month BEEMS Comprehensive Entrainment Monitoring Programme at Sizewell in 2011 (BEEMS Technical Report TR318) nor in any of the very large number of plankton surveys conducted at Sizewell. The totality of data from this extensive sampling programme led to the conclusion in BEEMS Technical Report TR318 that whilst glass eels are present in Sizewell coastal waters, that their density was very low at this location. The potential impact of glass eel entrainment in SZC was therefore assessed as negligible, especially given the high measured survival in laboratory studies that mimic the physical and chemical conditions and time of exposure and that any entrained glass eels would encountered within the power station (BEEMS Technical Report TR318).

During stakeholder engagement on the effects of SZC on fish, stakeholders have questioned whether the BEEMS surveys would have adequately detected glass eels. In particular, it has been suggested that:

1. the glass eel specific surveys targeted the surface waters during daylight when glass eels would have been seeking refuge near the seabed.
2. all of any glass eels sampled in the entrainment monitoring programme could have crawled out of the sampling nets before the nets were emptied.

These points have been carefully considered. In relation to point 1, the eel behaviour described is from upper estuaries not in lower estuaries or coastal waters (Harrison et al., 2014). At Hinkley Point (i.e. in the lower estuary) large numbers of glass eels were successfully sampled using the same methodology employed at Sizewell of sampling in the upper part of the water column during the daytime on the flood tide. As expected virtually no glass eels were detected on the ebb tide which is the behaviour that would be expected from fish using selective tidal stream transport (STST) to migrate on all of the available flood tides. This confirms that glass eels do migrate during daylight hours on flood tides at such locations and not just at night. This is supported by Lambert et al., (2007) where 30% of glass eels were found to migrate on the flood by day in the lower section of the Gironde estuary. Glass eels have poor swimming abilities and STST is the most energy efficient means of transport. Based upon the relative timings of eel arrivals in UK estuaries it is considered likely that glass eels employ STST on flood tides in coastal waters during day and night, particularly where underwater light levels are low due to high suspended sediment concentrations such as on the UK east coast. The question of whether the BEEMS surveys were too late could also be posed. The sample timings were determined from known glass eel arrival times on the UK east coast. For example, Environment Agency monitoring at Beeleigh Cut on the Blackwater (i.e. to the south of Sizewell where glass eel densities would be expected to be higher than off Sizewell assuming their likely southern migration route around the UK) showed that peak glass eels numbers were detected in May with substantial numbers in April and June but very low numbers of arrivals in March which would imply that the BEEMS survey timing (in April and May) was appropriate. The year 2015 could also have been a year of anomalously low glass eel recruitment but Figure 6 shows that this was not the case and in fact 2015 was a year that reflected the increase in glass eel recruitment observed across Europe from 2011 onwards described in Section 7.6.4.1. The BEEMS targeted glass eel surveys are, therefore, not considered invalid and if substantial number of glass eels were present at Sizewell the surveys would have detected them.

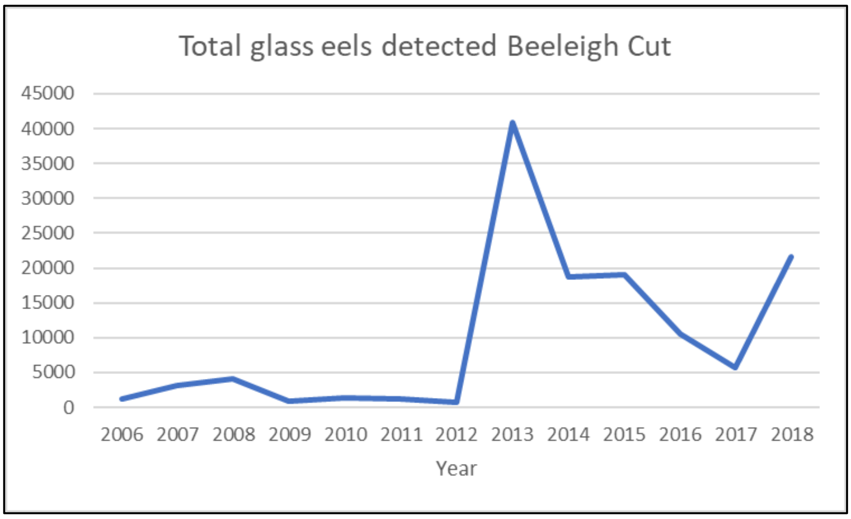

Figure 6 EA monitoring data for upriver glass eel migration from the Blackwater in Essex.

In relation to the second point, glass eels are indeed known to crawl to overcome barriers but this is reported behaviour from upper estuaries:

"*Although STST is the primary mechanism facilitating migratory passage through estuaries, where tidal effects become weaker in upper estuarine zones, a behavioural shift to active swimming is necessitated to effect further dispersion upstream at the freshwater interface or more certainly from the point where they accumulate glass eels change their behavioural pattern and actively migrate counter current. Such an active migration is revealed in the 'crawling' behaviour that glass eels display on trapping ladders."* Harrison et al., 2014.

The crawling behaviour described by stakeholders is a behavioural change associated with the tidal interface not in the coastal zone. Even if glass eels in the marine environment can climb barriers, the net sides in the entrainment sampling tanks were very steep and Cefas considers it highly unlikely that, if any eels had been caught, that all would have climbed out of all of the many nets deployed. In particular, the pump used to sample the SZB forebay for the entrainment sampling was not selected to ensure the survival of glass eels and the small impellor size would have delivered glass eels either moribund or dead into the sampling nets, substantially reducing the possibility of escapement from the sampling nets. In addition, the sampling pump was inspected after each of the 40 entrainment sampling events and no eels were found within the pump or its strainer. On a weight of evidence based approach, we are therefore confident that any glass eels caught in the entrainment sampling system would have most likely been retained by the sampling system and not have escaped.

In conclusion, the glass eel migration pattern around the UK, the strength and direction of coastal currents and the large number of freshwater rivers that the eels would encounter on route would mean that glass eel densities at Sizewell would be expected to be very low and amongst the lowest on the UK coast (on the eel migration route). This low density conclusion is supported by monitoring data. However, that monitoring data does confirm that a few glass eels do transit past Sizewell whilst seeking freshwater signals. On energy efficiency grounds this migration is most likely to use a form of STST in near surface waters. When the tide is in the 'wrong' direction the evidence suggests that glass eels are stationary on, or even buried in the bottom sediments to avoid being carried away from their preferred migration course. Such a migration strategy will mean that there is a low risk of abstraction into power stations with bottom mounted intakes which do not abstract surface water except minimally at slack water. The deeper the intakes, the lower the risk of abstraction. It would therefore be expected that glass eel abstraction at SZB would be greater than at SZC due to substantially deeper water at the proposed SZC intakes. The abstraction risk zone for the SZC intake heads depends on the swimming ability of the species. Glass eels are weak swimmers and can sustain approximately 0.25 m/s for only 3 minutes before exhaustion and have a sustained swimming speed of no more than 0.05 m/s for long periods (McCleave 1980). Glass eels resting on the seabed would be unlikely to be abstracted as the SZC intake surfaces would be 1.5 to 3.5m above the bed. The only times that glass eels would be at risk is when they were settling towards or moving off the seabed and then only for those that were within a worst case 7 m of the intakes (entrapment risk zone where velocities exceed 0.05 m/s). This represents a very small volume of water at the SZC intakes compared to the potential volume that the eels could settle in within Sizewell Bay and the abstraction risk is, therefore, considered minimal. The same argument would apply at SZB (whilst recognising that the risk would probably be larger due to the shallower water at the SZB intakes). Low entrapment potential combined with the expected low glass eel densities at the site and their migration pattern in surface waters would provide a coherent explanation of the absence of glass eels in the SZB entrainment monitoring surveys.

The targeted glass eel surveys only detected 1 individual from which it is not possible to deduce anything about their spatial distribution in Sizewell Bay and, in particular, whether the expected density would be lower or higher at the SZC intakes than at the SZB intakes. However, it is known that glass eels are seeking a freshwater signal as a cue to migrate up estuary. Due to dilution and the effects of tidal advection, the probability of detecting such signals will reduce rapidly with distance from the coast especially given the very strong shore parallel tidal currents along the Suffolk coast and the presence of offshore sandbanks. Many of the freshwater discharges on the East Anglian coast are relatively small, especially in the vicinity of Sizewell e.g. the Blyth and discharges from the Minsmere sluice, and such small signals in combination with the effects of dilution and tidal advection would indicate that a close to shore migration strategy would be the most likely to be allow the eels to find estuaries. On that basis the working hypothesis is that glass eels migrating on the coast will preferentially swim close to the coast and that their density offshore at the location of the SZC intakes would be lower than at the SZB intakes. Some evidential support for this hypothesis is provided by glass eel behaviour in lower estuaries where it is known that they occur in the highest densities closest to the shore when migrating up the estuary (for example in the Severn Estuary, BEEMS Technical Report TR274).

Considering the totality of the monitoring evidence and the implications of glass eel migration pattern around the UK, it is considered that the conclusions in BEEMS Technical Report TR318 that the density of glass eels off Sizewell was very low and that the risk of any significant entrainment effects on glass eel recruitment would be negligible is supported by the evidence.

Yellow eels

SZB impingement monitoring during the CIMP programme (with 10 mm mesh filtration) detected 2 glass eels (67.5 mm long) and a number of yellow eels ranging in length from 228 mm to 893 mm (

Figure 7 and Figure 8) i.e. with body widths from 14.25 mm to 55.8 mm (using morphological data reported in Environment Agency 2005). Ninety percent of the impinged eels were greater than 280 mm in length with a median length of approximately 400 mm. The length distribution of yellow eels is similar to that obtained from impingement sampling at Hinkley Point B. Studies to determine the age of the eels caught at Sizewell have not been undertaken but assuming a similar growth curve to that found at Oldbury in the Severn Estuary (Bird *et al* 2008), the yellow eels impinged at Sizewell B ranged from 2 to >25 years old. Yellow eels were caught throughout the year with the peak period of impingement in October and November and lowest catches in February to April and in December (Figure 9). From the length data and the SZB 10 mm mesh size it can reasonably be hypothesised that small (i.e. very young) yellow eels and elvers were not present at Sizewell; if young yellow eels had been present the length distribution would have been expected to continue down to below 160mm. Similarly, elvers were unlikely to have been present in any significant numbers as these larger fish would have been more likely to have been impinged than the two glass eels and would be unlikely to be present without young yellow eels. No glass eels or elvers were found in entrainment sampling. From these data it was concluded that yellow eels above 228 mm will be at risk of impingement at SZC with the majority of fish at risk having a length greater than 280 mm. All of the yellow eels are expected to be able to pass through the proposed 75 mm trash bar spacing at SZC.

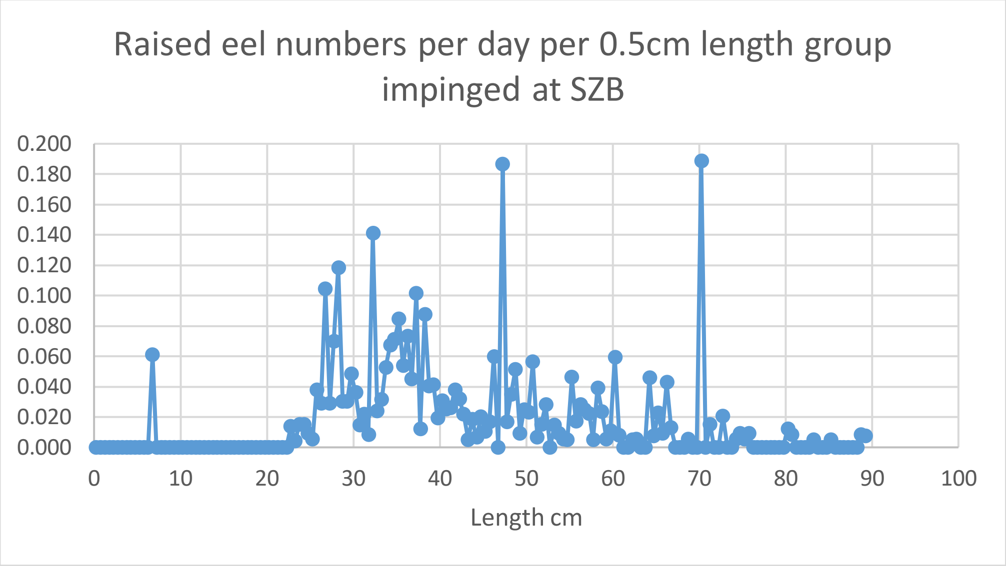

Figure 7 SZB impinged eel length frequency 2009-2017. The peak at 6.75cm corresponds to the 2 glass eels that were impinged in the period.

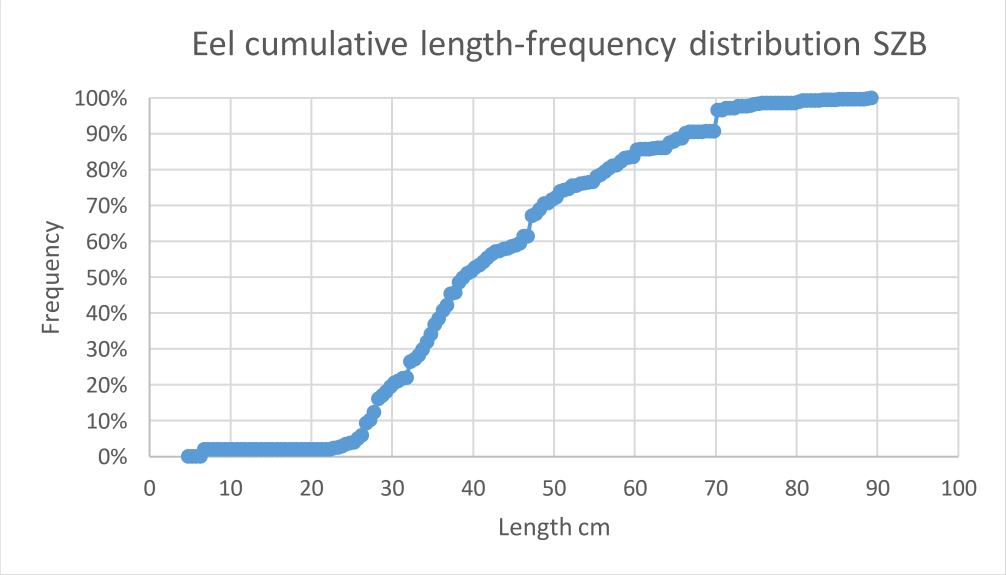

Figure 8 SZB impinged eel cumulative length frequency distribution 2009-2017.

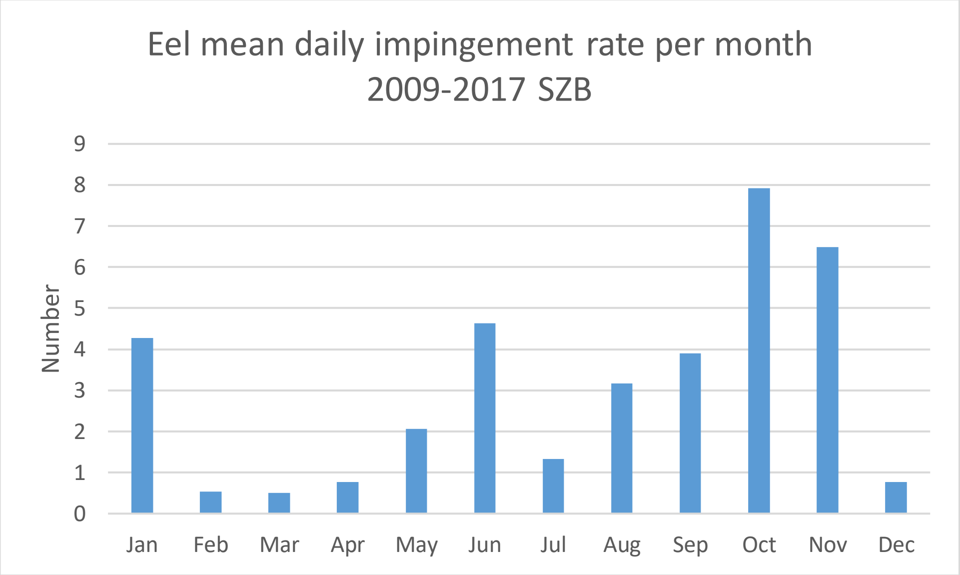

Figure 9 Variation in mean impingement rates by month at SZB.

Silver eels

No silver eels were caught in the SZB CIMP programme but this is not surprising as this life stage is known to migrate near to the surface at night and would be at a low risk of impingement at SZB's seabed mounted intakes and much less at SZC due to the deeper intakes.

7.6.4.4 *Assessment of predicted effects of SZC*

Although comparisons of eel mortalities due to impingement with population estimates for individual catchments are theoretically possible, there is uncertainty as to which are the relevant populations, and the European eel is considered to be a single reproductive stock throughout its distribution range. Given the small scale of the yellow and silver eel fisheries along the Suffolk coast, the most appropriate indicator of the perceived impact of the Sizewell power station on local eel stocks is considered to be a comparison between impingement data for eels by life stage, (raised to an equivalent silver eel biomass assuming 90 g for males, 570 g for females and a 1:1 sex ratio Dr. A. Walker, Cefas, pers. comm.) and, for fisheries, the combined mean yellow and silver eel catch for 2010-2017 (13.9 t) and, for the population, the mean estimated silver eel production for the Anglian RBD (78.6 t).

Based on the scaled-up CIMP dataset and assuming that the proposed LVSE intake head design and the FRR were fitted, the total annual predicted impingement of eel at a SZC, would be about 356 fish. Using a length-weight conversion factor of 0.329 kg per fish derived assuming a 50:50 sex ratio, that males mature at 89.9g and that females mature at 568.9g (Aprahamian, 1988), 356 eels equates to 0.12 t, equivalent to 0.15 % of the estimated RBD biomass. This latter figure is an overestimate as due to the lack of necessary biological and population data, it has not been possible to date to derive an EAV for eel, so a worst-case value of 1 has been assumed. Based on the eye index (Beullens *et al*., 1997) of biologically sampled impinged individuals at SZB (n = 89), all eels impinged were yellow eels and would have had an EAV of < 1 due to the natural mortality experienced by yellow eels in their many year growth period before maturation to silver eels. For example, the natural mortality of yellow eels is estimated to be 13% per annum, Dekker 2000. The yellow eels abstracted at SZB were in the age range 2 to >25 years and the majority would have remained at the yellow stage for many years before maturation. Assuming that the yellow eels would have spent an average of 5 years at Sizewell before maturation, the predicted SZC impingement effect would be reduced by 50% to 0.075% of the RBD silver eel biomass.

Another means of putting the SZC impingement estimate into context is to consider the predicted eel loss of 0.12 t per annum in the context of the estimated total EU anthropogenic impact on the stock of approximately 4,900 t per annum (Section 7.6.4.1). I.e. The SZC impact is equivalent to 0.002% of the total EU anthropogenic impact (from licenced fishing and secondly from hydropower and pumps operating largely in rivers).

As justified above and in BEEMS Technical Report TR318, the predicted effect of SZC entrainment on glass eel recruitment from SZC is considered negligible.

Compared to the other anthropogenic impacts on the stock, the predicted SZC entrapment effect on the EU component of the European eel stock is more than 4 orders of magnitude lower.

7.6.5 North Sea Herring and Blackwater Herring

The predicted effect of herring impingement in SZC is a negligible 0.01% SSB or 132 t per annum (Table 14).

The North Sea herring population has the following characteristics:

- North Sea Herring have multiple spawning grounds in the North Sea and eastern English Channel
- The different spawning populations are not genetically distinct.
- Scientific hypothesis: There is one population which is mixed during summer feeding and which migrates down the North Sea with subsets separating off to breed on route using broadly defined spawning areas as autumn, winter and finally spring spawners. The migration proceeds from Shetland to the eastern Channel and then northwards again (including some movement along the east Anglian coast from the Thames to the Humber)
- Different breeding times produce different growth patterns but the morphometric differences between fish are generally unreliable as an indicator of spawning type (autumn, winter, spring). Patterns in otolith rings are considered the most reliable indicator of spawning type.
- Blackwater herring are a spring spawning stock from February to April that spawn on the Eagle Bank at the entrance to the Blackwater Estuary in Essex and uniquely for North Sea herring have their own catch quota.

The main North Sea and Blackwater herring stocks are very different:

- The Blackwater stock is small with a management target for an SSB of at least 410 t.
- Historically the Blackwater stock was of little commercial interest due to the small size of the fish until the North Sea herring stock collapse that started in 1955 and the consequent reduction in landings. This stimulated commercial interest in the Blackwater stock that grew from 1958 with peak catches in 1972/73 of 600 t shortly followed by stock collapse and a complete closure of the fishery in 1979/80. The fishery reopened in 1980/81 under a management control regime designed to prevent a reoccurrence of overfishing.
- Recruitment to the Blackwater population has been poor in recent years and catches are now limited to 10 t per year for monitoring purposes from an SSB of approximately 200 t. An SSB of approximately 200 t is regarded as the minimum SSB to avoid stock collapse.
- The North Sea herring population has recovered to an SSB of greater than 2M tonnes but markets and fish landings are much lower than they were historically despite the substantial stock size.

Stakeholders have asked why herring impingement at Sizewell is considered to be from the main North Sea stock rather than the Blackwater stock.

As described above, the different stocks cannot be distinguished by genetics and so a weight of evidence approach has been used to ascribe origin to the herring impinged at Sizewell that considered:

- The timing of herring impingement at Sizewell compared with spawning in the Thames Estuary.

- Trends in SZB impingement rates compared with trends in the Blackwater SSB.
- The size of the SZB herring impingement and the implications if these fish had originated from the Blackwater stock.

Sizewell impingement is dominated by adults with numbers peaking in February and March and declining in April (BEEMS Technical Report TR345). Blackwater herring typically spawn at Eagle bank from the end February to mid-April (Fox 2001) and then return to southern North Sea feeding grounds. The coincident timing of spawning in the Thames Estuary and impingement at Sizewell indicates the fish caught at Sizewell are unlikely to be from the Blackwater. If Sizewell B was intercepting post spawning fish moving northwards, the peak catches would be expected in April or May with minimal catches in February when Blackwater herring are congregated in the Thames Estuary close to Eagle Bank.

The trend in impingement numbers at SZB has been increasing rapidly (Figure 10) which is contrary to the flat, possibly declining trend in the Blackwater SSB (Figure 11).

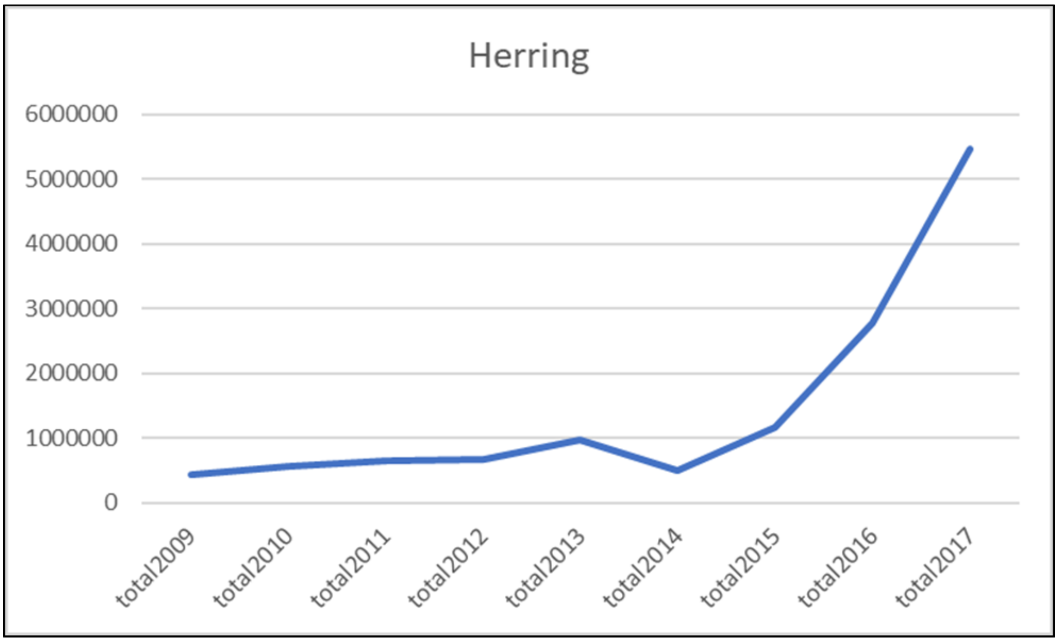

Figure 10 Herring impingement numbers at SZB (CIMP programme) by year.

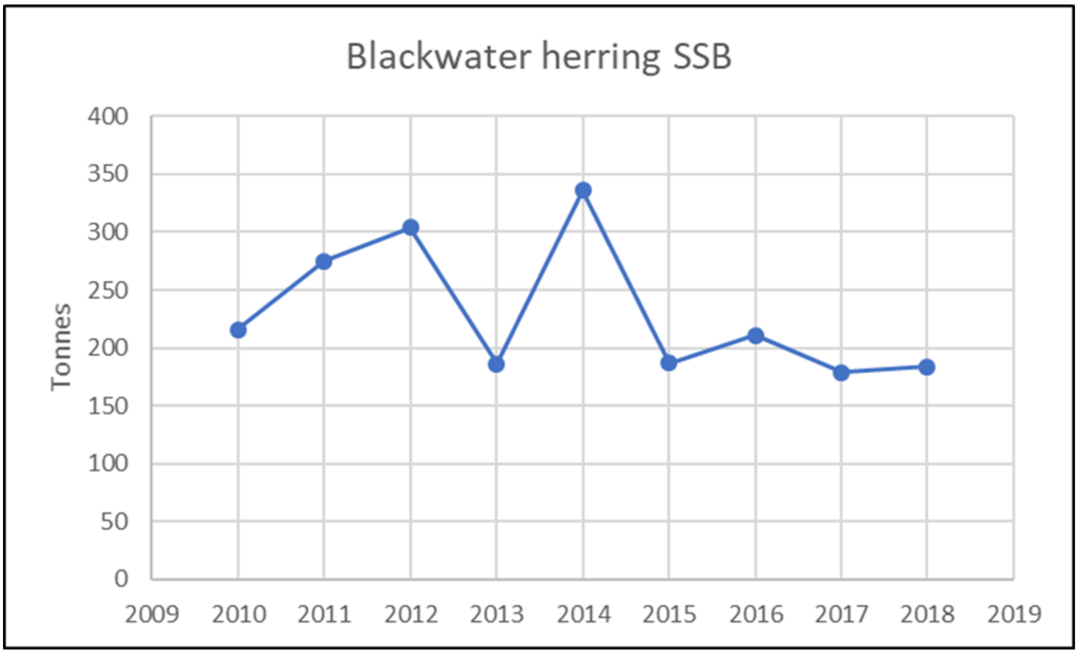

Figure 11 Change in the Blackwater herring SSB from 2010 to 2018 (Source Cefas).

Finally, the Blackwater SSB is less than or equal to 200 t at present (Figure 11). SZB annual mean herring impingement is estimated at 136 t (Appendix D2). If the SZB impingement was from the Blackwater herring stock that would represent an impingement impact of approximately 68% SSB that at the current SSB level would be completely unsustainable and lead to rapid total collapse of the stock to negligible levels and subsequently to minimal impingement at Sizewell. This has not happened, in fact SZB impingement numbers are increasing. This indicates that the SZB impingement is from the wider North Sea stock, not the Blackwater.

The weight of evidence therefore indicates that Sizewell impingement is from main North Sea stock (as assessed by ICES and used in this report) and not the Thames estuary Blackwater stock.

7.7 SZC predicted entrapment effects (impingement + entrainment)

In addition to the impingement of larger fish, invertebrates and other material, smaller organisms will also be abstracted by SZC but will not be retained on the drum screens. These smaller organisms will be entrained through the cooling water systems. The effects of entrainment on fish and other plankton is assessed in a separate report (BEEMS Technical Report TR318). Results indicated that apart from sand goby, the entrainment impacts for the key taxa present are significantly less than 1 %.

However, it is necessary to consider impingement and entrainment together, as a single entrapment impact for SZC. This is slightly complicated by the fact that the two data sets used for the respective assessments are different. For impingement the dataset spans 9 years, and the predictions are based on modelled mean monthly impingement values, using all year’s data. Impingement losses are considered against a mean SSB or landings value for the years 2009 – 2017 (the years of sampling). For entrainment, the predictions are based on a single year’s sampling (2010), and the losses were compared against the SSB and landings data for that year.

Entrapment has been estimated here by summing the % losses of impingement and entrainment. Although not a direct comparison of SSB or landings in a given year, given the extremely low entrainment losses of key taxa, when compared against SSB or landings, it would require annual changes in SSBs or landings of 2 or 3 orders of magnitude to significantly affect the combined total losses.

Combined impingement and entrainment estimated have been made for SZC:

a. without mitigation (Table 16);

b. with the proposed LVSE intake heads and FRR fitted (Table 17), and

c. With the impingement assessment with LVSE intakes and FRR systems fitted updated as detailed in section 7.5 for thin lipped grey mullet and bass (Table 18).

Results are similar to those obtained for impingement alone in that without mitigation only seabass, thin-lipped grey mullet, and European eel exceed 1 %. These species are joined by the sand goby for combined entrapment. With the proposed impingement mitigations, only sand goby exceeds 1 % of the stock comparator. However, sand goby is an unexploited short-lived stock and in such circumstances the appropriate comparator for negligible effects is with 10% of the SSB. As such the predicted entrapment of sand goby is negligible.

Table 16 Annual mean SZC entrapment predictions (impingement + entrainment) **with no impingement mitigation**. For impingement, losses have been converted to adult equivalent (EAV) numbers and weights (t) and calculated as a % of either the mean stock SSB (t) or mean international landings (t) for the period 2009-2017. For entrainment, the worst-case losses have been converted to EAV numbers and weight and calculated as a % of the SSB and landings in 2010 only. Species where the entrapment weight > 1 % of the relevant stock comparator (either SSB or landings – given in bold) are shaded red. Numbers in red font are either estimates of the population numbers (e.g. sand goby) or reported catch numbers (salmon & sea trout)

	Impingement						**Entrainment**						**Entrapment**			
Species	**EAV number**	**EAV weight**	**Mean SSB**	**% of SSB**	**Mean Landings**	**% of landings**	**EAV number**	**EAV weight**	**SSB 2010**	**% of SSB**	**Landings 2010**	**% of landings**	**EAV number**	**EAV weight**	**% of SSB**	**% of landings**
Sprat	5,352,978	56.23	220,757	0.03	151,322	0.04	199,715	2.00	225,041	0.00	143,500	0.00	5,552,693	58.23	**0.03**	0.04
Herring	1,827,944	344.87	2,198,449	0.02	400,244	0.09	23,992	4.18	2,023,720	0.00	187,600	0.00	1,851,936	349.05	**0.02**	0.09
Whiting	664,261	189.86	151,881	0.13	17,570	1.08	-	-	-	-	-	-	664,261	189.86	**0.13**	0.62
Bass	128,861	197.26	14,897	1.32	3,051	6.47	36	0.05	20,780	0.00	4,768	0.00	128,897	197.31	**1.32**	6.47
Sand goby	381,612	0.73	205,882,353	0.19	NA	NA	2,892,198	-	205,882,353	1.40			3,273,810		**1.59**	NA
Sole	53,233	11.40	43,770	0.03	12,800	0.09	631	0.14	31,358	0.00	12,603	0.00	53,864	11.54	**0.03**	0.09
Dab	66,211	2.70	NA	NA	6,135	0.04	21,810	0.87	NA	NA	8,279	0.01	88,021	3.57	NA	**0.05**
Anchovy	71,952	1.49	NA	NA	1,625	0.09	2,869	0.06	NA	NA	727	0.01	74,821	1.55	NA	**0.10**
Thin-lipped grey mullet	5,642	2.93	NA	NA	120	2.45	-	-	-	-	-	-	5,642	2.93	NA	**2.45**
Flounder	17,631	1.44	NA	NA	2,309	0.06	2	0.00	NA	NA	3,365	0.00	17,633	1.44	NA	**0.06**
Plaice	8,734	2.15	690,912	0.00	80,367	0.00	-	-	-	-	-	-	8,734	2.15	**0.00**	0.00
Smelt	18,170	0.30	105,733,825	0.02	8	3.56	-	-	-	-	-	-	18,170	0.30	**0.02**	3.56
Cod	6,049	15.74	103,025	0.02	34,701	0.05	-	-	-	-	-	-	6,049	15.74	**0.02**	0.03
Thornback ray	2,082	6.65	NA	NA	1,573	0.42	-	-	-	-	-	-	2,082	6.65	NA	**0.42**
River lamprey	6,720	0.53	62	0.86	1	47.65	-	-	-	-	-	-	6,720	0.53	**0.86**	47.65
Eel	4,516	1.49	79	1.89	14	10.70	-	-	-	-	-	-	4,516	1.49	**1.89**	10.70
Twaite shad	3,601	1.13	7,519,986	0.05	1	84.60	-	-	-	-	-	-	3,601	1.13	**0.05**	84.60
Horse mackerel	4,077	0.57	NA	NA	20,798	0.00	-	-	-	-	-	-	4,077	0.57	NA	**0.00**
Mackerel	628	0.20	3,888,854	0.00	1,026,828	0.00	-	-	-	-	-	-	628	0.20	**0.00**	0.00
Tope	64	0.44	NA	NA	498	0.09	-	-	-	-	-	-	64	0.44	NA	**0.09**
Sea trout	10	0.02	NA	NA	39,795	0.02	-	-	-	-	-	-	10	0.02	NA	**0.02**
Allis shad	5	0.00	27,397	0.02	0	1.79	-	-	-	-	-	-	5	0.00	**0.02**	1.79

Species	Impingement						Entrainment						Entrapment			
	EAV number	EAV weight	Mean SSB	% of SSB	Mean Landings	% of landings	EAV number	EAV weight	SSB 2010	% of SSB	Landings 2010	% of landings	EAV number	EAV weight	% of SSB	% of landings
Sea lamprey	5	0.01	NA	NA	NA	NA	-	-	-	-	-	-	5	0.01	NA	NA
Salmon	0	0.00	NA	NA	38,456	0.00	-	-	-	-	-	-	0	0.00	NA	**0.00**

Table 17 Annual mean SZC entrapment predictions (impingement + entrainment) **considering the effect of the intake head design and with FRR systems fitted**. Losses have been converted to adult equivalent (EAV) numbers and weights (t) and calculated as a % of either the mean stock SSB (t) or mean international landings (t). Species where the impingement weight > 1 % of the relevant stock comparator (either SSB or landings – given in bold) are shaded red. Numbers in red font are either estimates of the population numbers (e.g. sand goby) or reported catch numbers (salmon & sea trout)

	Impingement						**Entrainment**						**Entrapment**			
Species	**EAV number**	**EAV weight**	**Mean SSB**	**% of SSB**	**Mean landings**	**% of landings**	**EAV number**	**EAV weight**	**SSB 2010**	**% of SSB**	**Landings 2010**	**% of landings**	**EAV number**	**EAV weight**	**% of SSB**	**% of Landings**
Sprat	2,050,190	21.53	220,757	0.01	151,322	0.01	199,715	2	225,041	0.00	143,500	0.00	2,249,905	23.53	**0.01**	0.01
Herring	700,103	132.08	2,198,449	0.01	400,244	0.03	23,992	4	2,023,720	0.00	187,600	0.00	724,095	136.26	**0.01**	0.03
Whiting	140,044	40.03	151,881	0.03	17,570	0.23	-	-	-	-	-	-	140,044	40.03	**0.03**	0.13
Bass	27,172	41.6	14,897	0.28	3,051	1.36	36	0	20,780	0.00	4,768	0.00	27,208	41.65	**0.28**	1.36
Sand goby	30,108	0.06	205,882,353	0.01	NA	NA	2,892,198	-	205,882,353	1.40	0	0.00	2,922,306		**1.42**	0.00
Sole	4,200	0.9	43,770	0	12,800	0.01	631	0	31,358	000	12,603	0.00	4,831	1.04	**0.00**	0.01
Dab	13,656	0.56	NA	NA	6,135	0.01	21,810	1	NA	NA	8,279	0.00	35,466	1.43	NA	**0.02**
Anchovy	27,558	0.57	NA	NA	1,625	0.04	2,869	0	NA	NA	727	0.00	30,427	0.63	NA	**0.05**
Thin-lipped grey mullet	1,190	0.62	NA	NA	120	0.52	-	-	-	-	-	-	1,190	0.62	NA	**0.52**
Flounder	1,559	0.13	NA	NA	2,309	0.01	2	0	NA	NA	3,365	0.00	1,561	0.13	NA	**0.01**
Plaice	689	0.17	690,912	0	80,367	0	-	-	-	-	-	-	689	0.17	**0.00**	0.00
Smelt	6,959	0.12	105,733,825	0.01	8	1.36	-	-	-	-	-	-	6,959	0.12	**0.01**	1.36
Cod	1,395	3.63	103,025	0	34,701	0.01	-	-	-	-	-	-	1,395	3.63	**0.00**	0.01
Thornback ray	164	0.52	NA	NA	1,573	0.03	-	-	-	-	-	-	164	0.52	NA	**0.03**
River lamprey	530	0.04	62	0.07	1	3.76	-	-	-	-	-	-	530	0.04	**0.07**	3.76
Eel	356	0.12	79	0.15	14	0.84	-	-	-	-	-	-	356	0.12	**0.15**	0.84
Twaite shad	1,379	0.43	7,519,986	0.02	1	32.40	-	-	-	-	-	-	1,379	0.43	**0.02**	32.40
Horse mackerel	1,561	0.22	NA	NA	21,442	0	-	-	-	-	-	-	1,561	0.22	NA	**0.00**
Mackerel	241	0.08	3,888,854	0	1,026,828	0	-	-	-	-	-	-	241	0.08	**0.00**	0.00
Tope	5	0.03	NA	NA	498	0.01	-	-	-	-	-	-	5	0.03	NA	**0.01**
Sea trout	4	0.01	NA	NA	39,795	0.01	-	-	-	-	-	-	4	0.01	NA	**0.01**
Allis shad	2	0	27,397	0.01	0	0.68	-	-	-	-	-	-	2	0.00	**0.01**	0.68
Sea lamprey	0	0	NA	NA	NA	NA	-	-	-	-	-	-	0	0.00	NA	NA

Species	Impingement						Entrainment						Entrapment			
	EAV number	EAV weight	Mean SSB	% of SSB	Mean landings	% of landings	EAV number	EAV weight	SSB 2010	% of SSB	Landings 2010	% of landings	EAV number	EAV weight	% of SSB	% of Landings
Salmon	0	0	NA	NA	38,456	0	-	-	-	-	-	-	0	0.00	NA	**0.00**

Table 18 Annual mean SZC entrapment predictions (impingement + entrainment) **considering the effect of LVSE intake heads and FRR systems fitted and the corrections to thin lipped grey mullet and bass impingement assessment detailed in Section 7.5 (main changes shown in yellow)**. Losses have been converted to adult equivalent (EAV) numbers and weights (t) and calculated as a % of either the mean stock SSB (t) or mean international landings (t). Species where the impingement weight > 1 % of the relevant stock comparator (either SSB or landings – given in bold) would be shaded red (there are none in this Table) with the exception of sand goby where a 10% of SSB or landings comparator has been used. Numbers in red font are either estimates of the population numbers (e.g. sand goby) or reported catch numbers (salmon & sea trout)

Species	Impingement						Entrainment						Entrapment			
	EAV number	EAV weight	Mean SSB	% of SSB	Mean landings	% of landings	EAV number	EAV weight	SSB 2010	% of SSB	Landings 2010	% of landings	EAV number	EAV weight	% of SSB	% of Landings
Sprat	2,050,190	21.53	220,757	0.01	151,322	0.01	199,715	2	225,041	0.00	143,500	0.00	2,249,905	23.53	**0.01**	0.01
Herring	700,103	132.08	2,198,449	0.01	400,244	0.03	23,992	4	2,023,720	0.00	187,600	0.00	724,095	136.26	**0.01**	0.03
Whiting	140,044	40.03	151,881	0.03	17,570	0.23	-	-	-	-	-	-	140,044	40.03	**0.03**	0.13
Bass	2,717	4.16	14,897	0.03	3,051	0.14	36	0	20,780	0.00	4,768	0.00	2,753	4.16	**0.03**	0.14
Sand goby	30,108	0.06	205,882,353	0.01	NA	NA	2,892,198	-	205,882,353	1.40		0.00	2,922,306		**1.41**	0.00
Sole	4,200	0.9	43,770	0	12,800	0.01	631	0	31,358	0.00	12,603	0.00	4,831	1.04	**0.00**	0.01
Dab	13,656	0.56	NA	NA	6,135	0.01	21,810	1	NA	NA	8,279	0.00	35,466	1.43	NA	**0.02**
Anchovy	27,558	0.57	NA	NA	1,625	0.04	2,869	0	NA	NA	727	0.00	30,427	0.63	NA	**0.05**
Thin-lipped grey mullet	1,190	0.62	600	0.10	120	0.52	-	-	-	-	-	-	1,190	0.62	**0.10**	0.52
Flounder	1,559	0.13	NA	NA	2,309	0.01	2	0	NA	NA	3,365	0.00	1,561	0.13	NA	**0.01**
Plaice	689	0.17	690,912	0	80,367	0.00	-	-	-	-	-	-	689	0.17	**0.00**	0.00
Smelt	6,959	0.12	105,733,825	0.01	8	1.36	-	-	-	-	-	-	6,959	0.12	**0.01**	1.36
Cod	1,395	3.63	103,025	0.00	34,701	0.01	-	-	-	-	-	-	1,395	3.63	**0.00**	0.01
Thornback ray	164	0.52	NA	NA	1,573	0.03	-	-	-	-	-	-	164	0.52	NA	**0.03**
River lamprey	530	0.04	62	0.07	1	3.76	-	-	-	-	-	-	530	0.04	**0.07**	3.76
Eel	356	0.12	79	0.15	14	0.84	-	-	-	-	-	-	356	0.12	**0.15**	0.84
Twaite shad	1,379	0.43	7,519,986	0.02	1	32.40	-	-	-	-	-	-	1,379	0.43	**0.02**	32.40
Horse mackerel	1,561	0.22	NA	NA	20,798	0.00	-	-	-	-	-	-	1,561	0.22	NA	**0.00**
Mackerel	241	0.08	3,888,854	0	1,026,828	0.00	-	-	-	-	-	-	241	0.08	**0.00**	0.00
Tope	5	0.03	NA	NA	498	0.01	-	-	-	-	-	-	5	0.03	NA	**0.01**

Species	Impingement						Entrainment						Entrapment			
	EAV number	EAV weight	Mean SSB	% of SSB	Mean landings	% of landings	EAV number	EAV weight	SSB 2010	% of SSB	Landings 2010	% of landings	EAV number	EAV weight	% of SSB	% of Landings
Sea trout	4	0.01	NA	NA	39,795	0.01	-	-	-	-	-	-	4	0.01	NA	**0.01**
Allis shad	2	0	27,397	0.01	0	0.68	-	-	-	-	-	-	2	0.00	**0.01**	0.68
Sea lamprey	0	0	NA	NA	NA	NA	-	-	-	-	-	-	0	0.00	NA	NA
Salmon	0	0	NA	NA	38,456	0	-	-	-	-	-	-	0	0.00	NA	**0.00**

7.8 Consideration of potential local effects on the fish assemblage at Sizewell

In Section 7.7 the predicted SZC entrapment effect on fish populations has been assessed against ICES derived spawning stock biomasses (SSB) (or international landings as a highly precautionary proxy for SSB). Comparison against SSBs is the internationally recognised best practice way that the much larger effects of fishing at either a fleet or individual boat level are assessed.

SZC Stakeholders have indicated that in principle they agree with this assessment methodology, but questions have been raised on whether SZC will have any localised entrapment effects on fish. This section of the assessment considers that question in detail.

Section 5.10 describes how ICES decides on the definition of stock units based upon a mature weighting of the best available scientific evidence. As a result of decades of research, it is clear that the population structures of marine species fall along a continuum from panmictic (e.g. European eel, *Anguilla anguilla*) to numerous distinct sub-populations (e.g. North Sea herring, *Clupea harengus*) with the majority of species exhibiting complex structure. In the open sea, the sub-populations of many species mix to a considerable extent; especially during summer feeding and on nursery areas, with harvesting affecting multiple components of the overall population simultaneously. ICES' definition of stock units integrates all of the information on site fidelity to spawning, nursery and feeding areas together with knowledge of migration patterns and the degree of intermixing that takes place between any sub populations. Stock units are not static and change when the weight of evidence indicates that a change would be likely to lead to better assessments and management advice. At the request of SZC stakeholders, the specific status of the large bass stock area used in the SZC entrapment assessment was considered (Section 5.10.1). The current stock unit comprises ICES Divisions 4b-c, 7a and 7d-h (central and southern North Sea, Irish Sea, English Channel, Bristol Channel, and Celtic Sea) and SZC stakeholders have queried whether that area is appropriate based upon known bass site fidelities seasonally and at different life stages. The ICES bass working group is fully aware of this research which was weighed together with the extensive monitoring by EU member states (e.g. 27 bass nursey sites are monitored in the UK alone, Source Cefas) and the stock unit definition takes account of site fidelity and the degree of mixing between the sub populations. The stock unit was last reviewed in 2018 and found to fully appropriate based upon the evidence. Coordinated research is currently underway on bass stock identity, but the direction of that research may lead to a larger stock unit area, not a smaller one (Section 5.10.2).

In section 5.10.3 we concluded that ICES' stock boundaries are based on a mature weighing of all of the best scientific evidence available and considering the negligible predicted SZC impacts compared to those of fishing (Table 21 and Table 22, and the precautionary nature of ICES' estimates of SSBs, we could find no justification not to use the ICES' stock definitions to assess SZC effects on fish,

As explained previously, where SSB data do not exist the effects of SZC are compared with international landings from the stock unit which provides a highly precautionary estimate of effects as landings are less, normally much less, than stock sizes.

For some data poor stocks, there is no assessment of the SSB for the stock and in those cases the SZC assessment has, on a precautionary basis, assessed SZC effects by comparison against a part of the stock where only partial data are available. The effects assessment in those cases provides a precautionary overestimate of SZC effects (In this report such an assessment of SZC effects against partial stock estimates has been undertaken for European eel, twaite shad, allis shad, cucumber smelt and river lamprey).

7.8.1 Fish at Sizewell in a southern North Sea context

The fish species at Sizewell live and move in an unconstrained coastal environment with most species undertaking wide spatial migrations throughout the year; in particular migrating fish are not forced to pass close to power station intakes as could be the case in a narrow river or estuary. In the coastal environment at Sizewell any local reduction in fish numbers by SZC would be expected to be replaced by incoming species competing for habitat and food resources. Unlike in some estuarine environments, there are no unique features or resources that fish populations are dependent upon in the vicinity. For example, estuaries often function as nursery areas for young fish but the Sizewell area does not have an extensive nursery role for most species (see Section 7.8.2) as exemplified by the older and larger fish found at the site compared with an estuary such a Hinkley Point (Table 19). From Table 19 it can be seen that for the typical species listed, only Thornback Ray are larger at Hinkley Point than at Sizewell and for herring, whiting and cod, in particular, Sizewell has much lower numbers of 0 group (less than 1 year old) fish. (The lower the EAV in the range 0 to 1, the greater the proportion of juvenile fish with EAVs of around 0.1 or below consisting predominantly of 0 or possibly 1 group fish).

The fish assemblage at Sizewell is a reflection of the seasonal migrations of fish into and out of the area and fish lost at Sizewell C would be rapidly replaced by exchanges with populations from the wider southern North Sea.

Table 19 Differences in age and maturity of fish caught at Sizewell and Hinkley Point as reflected in Equivalent Adult Values (EAV) where an EAV of 1 is a mature adult.

Species	SZ EAV	HP EAV
Sprat	0.751	0.556
Herring	0.715	**0.113**
Whiting	0.356	**0.098**
Bass	0.224	0.121
Dover sole	0.213	0.236
Cod	0.359	**0.018**
Thornback Ray	0.193	0.339
Plaice	0.345	0.192

Note: EAVs are from BEEMS Technical Reports TR383 (Sizewell) and TR426 (Hinkley Point) respectively.

7.8.2 What local effects of SZC entrapment might be important?

If present, the following potential local effects could be important:

i. **If a reduction in local fish numbers adversely affected a spawning or nursery habitat in the vicinity of Sizewell that was critical to the sustainability of a stock.**
Limited local spawning does take place in the region of Sizewell, predominantly by Dover Sole and Anchovy (the two species contributed a total of 85% of measured egg numbers at Sizewell), but the measured egg density indicates that the area is not important to the species which are geographically widely distributed (BEEMS Technical Report TR318). Similarly, the Sizewell region provides some nursery habitat predominantly for gobies and sprat (86% of measured larval and juvenile fish numbers) but again the measured densities indicate that the area is of low importance for these two widely distributed species (BEEMS Technical Report TR318). For all of the species predicted to be entrained by SZC the predicted stock level effects are negligible (BEEMS Technical Report TR318). The importance of the Sizewell Bay area for fish spawning and nursery habitat is, therefore, low and there are much more important habitat areas over the southern North Sea and beyond (BEEMS Technical Report TR345).

ii. **If a reduction in local fish numbers adversely affected prey availability for predators**.
The local ecosystem is founded upon predator-prey relationships and so localised depletion of a prey resource could adversely affect the predator sustainability e.g. HRA protected marine birds predating on fish. Such food webs are routinely subject to high levels of natural variability and predators have evolved adaptation strategies to cope including prey species switching and changes to foraging behaviour. Predators will only be sensitive to large and sustained changes to prey

abundance unless their foraging range is small and their ability to change their foraging range is limited. Of the protected marine birds in the vicinity of Sizewell, little tern during the breeding season have by far the smallest foraging range (BEEMS Technical Report TR431) and could therefore be vulnerable to any localised depletion of fish prey due to SZC. Breeding little tern are designated in the Minsmere-Walberswick SPA however colony locations for this species are known to be highly variable with time. At classification in 1991, the SPA's breeding population was 28 breeding pairs however, since classification, the numbers of little tern using Minsmere-Walberswick SPA has decreased by approximately 95% to 1.6 breeding pairs (5 year mean peak count 2014-2018) (Natural England 2019).

The diet of breeding little tern at Sizewell is expected to consist of small schooling pelagic fish species that are found close to the sea surface and demersal fish in the shallows such as gobies. During the breeding season little tern forage close to their colonies out to a maximum distance of approximately 2.4 km offshore (TR431). They would not, therefore, be expected to be foraging offshore of the Sizewell- Dunwich Bank in the vicinity of the proposed SZC intakes at approximately 3km offshore and would instead be foraging inshore i.e. within the zone of abstraction impact from SZB. Impingement data, indicates that sprat and herring are the most common pelagic fish in Sizewell coastal waters (TR431). The predicted impingement mortality from SZB is 22 t of sprat and 135 t of herring per annum (Appendix D2). All abstracted fish are returned to sea from SZB but these pelagic species are not expected to survive impingement. Assuming sprat and/or herring accounted for the whole diet of little terns, the calculated biomass required to sustain 28 pairs (with up to 3 chicks per pair) during the 4-month breeding season is less than 650 kg per annum.

The predicted effect of the SZB losses on the recognised stocks of sprat and herring are negligible (Appendix D2). If SZB was having a significant effect on the local sprat and herring abundance this would be apparent in the impingement numbers (which would collapse). However, the herring population at Sizewell is increasing (Figure 10) and the sprat population is the largest of any fish population at Sizewell and shows no discernible trend. Acoustic survey results show no localised reduction of pelagic shoaling fish in the vicinity of the SZB intake (BEEMS Technical Report TR359) and it is apparent that localised losses at SZB are being replaced by the constantly moving shoals from the wider North Sea. Once SZC is operational the same pattern is expected with no discernible differences in pelagic fish abundance in the vicinity of the SZC intakes. However, fish density at SZC would be immaterial to little tern breeding success as the abstraction zone would be too far offshore for the area to be important to little tern foraging.

7.8.3 SZC Impingement Risk Zones and the potential for very local fish depletion

Fish are only likely to be impinged if they move into the zone of influence of the intake heads. For SZC, a tidally averaged worst case of approximately 0.7m from the intake faces would experience an intake velocity of 0.3 m/s (BEEMS Scientific Position Paper SPP099). Compared with the spatial domain that the migrating fish move within, this abstraction risk zone is very small. At first site this could be considered as the zone where localised effects would be observed. However, due to the continual replacements by fish from a wider area there is no such extremely local effect as demonstrated by the impingement time series data.

7.8.4 Evidence of localised impingement effects from other sites

When the Hinkley Point A (HPA) station closed down a seawater abstraction of 44 cumecs was removed from the Hinkley Point intake structure. If an impingement impact of the size of the HPA abstraction was having any effect on local fish populations then the closure should have been detectable in the 35+ years of the HPB impingement record. In practice no such effect could be detected, and it was concluded that the local fish assemblage was not sensitive to at least a 44 cumec reduction in unmitigated impingement pressure, BEEMS Technical Report TR456 (Note: HPA and HBP were not fitted with impingement mitigation measures). SZC would be fitted with the latest impingement mitigation technology e.g. LVSE intakes and an FRR system and to compare the impingement pressure exerted by the proposed station it is necessary to calculate an equivalent unmitigated abstraction (Table 20). For SZC this impact varies between 10.4 cumecs and 50.6 cumecs which for most species is less than the change in impingement of 44 cumecs that caused no detectable effect at Hinkley Point.

Table 20 SZC equivalent abstraction after impingement mitigation of LVSE intakes and FRR system in comparison with an unmitigated SZC abstracting 132 cumecs

Species group	**Equivalent SZC abstraction in cumecs compared with an unmitigated station abstracting 132 cumecs**
Pelagic	50.6
Demersal	27.8 – 30.3
Epibenthic	10.4

The only species that would experience an increase in impingement pressure that was greater than 44 cumecs would be the pelagic species (sprat, herring, anchovy, smelt, mackerel, horse mackerel, twaite shad and allis shad) where there would be a marginal increase in impingement pressure of 6.6 cumecs above the 44 cumec pressure that caused no detectable effect at Hinkley Point. Of these species only sprat and herring and to a much lower extent anchovy play an important role in the local food web and as discussed above they are widely distributed species that migrate continuously over very large spatial areas. The other 5 species (smelt, mackerel, horse mackerel, twaite shad and allis shad) are not abundant enough at Sizewell to be important to the local food web with only smelt having a non-trivial presence (Table 18).

The additional abstraction from SZC is not considered large enough to have any significant effect on pelagic fish numbers because, as explained above, SZC losses will be continuously replaced by pelagic fish moving into the local area from the wider southern North Sea.

7.8.5 SZC entrapment effects on smelt in the Alde Ore and potentially in the Blyth water bodies

Stakeholders have specifically asked whether SZC entrapment would significantly affect the abundance of smelt in the Alde Ore and possibly the Blyth water bodies.

The key facts about smelt in the vicinity of Sizewell are as follows:

i. Smelt are relatively common on the East Anglian coast. Comparative genomic analyses (BEEMS Technical Report TR423) have concluded that smelt from Sizewell and the Rivers Thames, Waveney, and Great Ouse are genetically homogeneous with no genetic structuring seen within the region indicating a single stock unit from at least the Greater Ouse to the Thames. Based upon fishing surveys it is considered likely that there is also a single population along the European coast from at least the Elbe to the Scheldt. The extent of mixing between the UK and European populations is currently unknown but based upon the comparative distances between the great Ouse and the Thames and Sizewell and the European coast the hypothesis is that there is a single southern North Sea population that mixes during summer feeding. This hypothesis is considered reasonable, but it is recognised that it has not yet been proven and appropriate samples for further genomic analyses are being acquired. The Elbe and the Scheldt have very large breeding populations of smelt and it is likely that they have extensive summer feeding grounds in the southern North Sea that may overlap areas used by UK sub populations.
ii. No smelt eggs or larvae are entrained at SZB as would expected given the known lifecycle of the species (Section 7.6.1).
iii. A breeding population in the Blyth is considered unlikely due to the lack of habitat and barriers to migration (Section 7.6.1).
iv. SZB does not impinge any 0-group smelt and predominantly catches 1yr old and older fish in the summer i.e. after the spring spawning period whilst the sub populations of the species are mixed on summer feeding grounds. Low numbers of fish are caught in the period early February to end April when mature adults would be spawning in rivers (BEEMS Technical Report TR345). SZB is not,

therefore, considered to be having any significant effects on smelt migrating to and/or from estuaries.

v. Smelt impingement numbers at SZB show no trend over the period 2009-2017 and numbers in that period are similar, possibly larger than in 1981/82. There is, therefore, no evidence that effects of fishing and anthropogenic mortality on the stock are unsustainable.

vi. Assessments of SZC entrapment effects compared with both UK landings (i.e. assuming an Anglian stock unit) or assuming a southern North Sea stock unit are both negligible (Section 7.6.1).

The weight of evidence is, therefore, that SZC entrapment will have no significant effect on any sub population of smelt in the Alde Ore. The Blyth is not considered to possess a spawning sub population due to a lack of suitable habitat.

7.8.6 Conclusions on potential local effects from SZC entrapment

An assessment of potential localised effects of SZC entrapment was undertaken and found no likely significant adverse effects on:

i. spawning or nursery areas in the vicinity of Sizewell

ii. the prey of HRA protected breeding little tern (the potentially most vulnerable species to localised effects on prey fish abundance at Sizewell)

7.9 Contextualising SZC entrapment losses

To place the predicted fish losses due to entrapment by SZC (Table 18) into context two analyses are presented:

i. Table 21 shows a comparison for those stocks where data are available between mean fishery landings as a percentage of SSB and SZC entrapment as a percentage of SSB for the period 2009-2017.

ii. Table 22 shows discarded fish weight as a percentage of landed weight by year for commercially exploited species compared with ICES records of fishery discards. The same table also shows predicted mean SZC entrapment weights as a percentage of the mean landings for each species.

Table 21 Comparison of mean fishery landings as a percentage of SSB with predicted SZC mean entrapment as a percentage of SSB for the period 2009-2017.

Species	Fisheries Landings as % SSB	SZC entrapment losses as % of SSB	Notes
Sprat	69%	0.01%	
Herring	18%	0.01%	Commercial market reduced after stock collapse and subsequent recovery
Whiting	20%	0.03%	
Bass	20%	0.03%	
Sole	29%	0.00%	
Plaice	12%	0.00%	
Cod	45%	0.00%	
Mackerel	26%	0.00%	
River lamprey	2%	0.07%	SSB is of Derwent population only. Landings and effort are restricted by licences.
Eel	18%	0.15%[1]	SSB is of Anglian RBD only.

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[1] SZC effect overestimated due to use of incorrect EAV.

Table 21 shows that the fishery impact on each stock is much greater than that of SZC entrapment, often by orders of magnitude.

Table 22 Discards by year as a percentage of landed fish weight compared with predicted SZC entrapment as a percentage of landed fish weight.

Year	Cod	Sole	Plaice	Dab	Whiting	Flounder	Horse mackerel	Mackerel
2008	93.2	1.9	44.4	316.7	57.4	44.9	-	3.9
2009	62.8	4.3	39.5	474.7	54.5	47.9	-	3.6
2010	33.6	8.3	35.5	513.2	73.5	97.5	-	0.4
2011	27.2	7.2	33.6	599.0	66.1	55.7	-	0.6
2012	26.9	9.0	44.2	746.9	73.6	55.0	-	0.5
2013	33.8	11.2	25.2	808.9	46.4	80.9	-	0.1
2014	30.4	6.5	39.6	1064.7	66.6	59.1	-	0.1
2015	33.5	6.9	35.1	932.2	109.8	69.7	20.0	0.0
2016	32.0	5.4	30.4	881.2	107.2	35.9	11.1	0.2
2017	23.1	5.8	31.5	875.9	91.0	47.3	9.1	0.1
SZC Entrapment (% of landed weight)	0.01	0.01	0.00	0.02	0.23	0.01	0.00	0.00

For commercially important species, SZC entrapment losses are lower than <1% of landings. Discards as a percentage of landings weights vary dramatically depending on the species. However, entrapment losses are at least two orders of magnitude lower than the proportion of landed fish that is discarded annually. Expressing the results as weights can provide an even more compelling illustration and for example, the mean weight of cod discarded between 2009 and 2017 was 12,980 t whereas the predicted mean SZC entrapment loss for the same period was 3.6 t.

8 Shellfish impingement predictions for SZC

Four shellfish species (brown crab *Cancer pagurus*, European lobster *Homarus gammarus*, brown shrimp *Crangon crangon* and whelk *Buccinum undatum*) were defined as key benthic species on the basis of their socio-economic importance (all four species) and their ecological importance (brown shrimp only) (BEEMS Technical Report TR348). Of these, whelk were absent from the impingement dataset. The impact of SZC on whelks is therefore considered negligible and the species will not be considered further. Estimates of SZB and predictions of SZC impingement were made using the same methods described for the finfish species.

8.1 FRR system mortality

8.1.1 Trash rack mortality

As with finfish, the proportion of the shellfish species that would pass through the 75 mm trash rack was assessed (Table 23). For brown crab, carapace width (CW, mm) measurements were made on crabs sampled at the SZB site between 2014 and 2017 and used to calculate annual length distributions. The maximum width observed was > 75 mm, and the proportion that is likely to pass was calculated in a similar manner to finfish species. Only four lobsters were recorded in the CIMP dataset between 2009 and 2017, all of them prior to 2014. Only weights were recorded, and these were used to estimate the proportion that would pass through a 75 mm bar spacing.

Table 23 Proportion of shellfish, by species that will not pass through the 75 mm wide trash racks

Species	Calculation type	Size of largest SZB individual (mm)	Proportion not passing through trash rack	Comment
Brown shrimp	Group 1	Not measured	0.000	All shrimp will pass
Brown crab	Group 3	162	0.014	Calculate length at 75 mm width
Lobster		Not measured	0.500	Best estimate based on individual weights

8.1.2 FRR survival

According to Environment Agency (2005), crustaceans will have the same FRR survival rates as other epibenthic species. Therefore, for this report, the modified values for the epibenthic group (given in Section 5.7.2 were used here for shellfish (Table 24).

Table 24 Proportion mortality by species through the SZC drum and band screens

	Proportion lost		
	Drum	Band	Species group
Brown shrimp	0.206	0.206	epibenthic
Brown crab	0.206	0.206	epibenthic
Lobster	0.206	0.206	epibenthic

8.2 EAV conversions

An EAV value was calculated for brown crab. EAVs could not be calculated for brown shrimp and lobster due to a lack of size data and other biological data. For those species an EAV of 1 was used (Table 25), giving rise to impingement overestimates.

Table 25 EAV metrics and mean weight of individuals used to convert the numbers impinged to adult equivalent numbers and weights of shellfish at SZC. (See BEEMS Technical Report TR383 for brown crab EAV calculations)

Species	EAV	Mean weight per individual (kg)	Data source for mean weight
Brown shrimp	1.000	0.0013	Calculated from modelled mean number and mean weight of brown shrimp at SZB
Brown crab	0.219	0.5	Mean male and female weights at the minimum landings size, (87mm CW), and averaged assuming a 50:50 sex ratio
Lobster	1.000	0.379	Bannister et al. (1983)

8.3 Evaluating SZC impacts on shellfish

Assessments have been carried out by Cefas for lobsters and brown crabs in the southern North Sea, using slightly different assessment areas for the two species. Due to uncertainties in the data, SSB estimates are not available, and impingement losses were compared against the landings from the rectangles in the assessment regions (Table 26). None of the crustacean species is assigned to an ICES Working Group.

Table 26 Data sources used to provide information on relevant stock unit, landings and SSB

Species	Stock unit	Assessment type	Impingement effect comparator	Reference
Brown shrimp	Not defined	None	Landings, same ICES rectangles as lobster assessment	
Brown crab	Southern North Sea	Analytical assessment, but with many uncertainties	Landings from the Southern North Sea crab fishery unit (CFU) (as defined in Cefas 2017) ICES rectangles in the assessed area are shown in Table 27.	Cefas, 2017
Lobster	East Anglia	Analytical assessment, but with many uncertainties	Landings from East Anglia Lobster Fishery Unit (LFU). ICES rectangles in the assessed area are shown in Table 28.	Cefas, 2017b

Table 27 ICES Rectangles in Southern North Sea CFU

35F0	35F1	35F2	35F3	35F4	35F5	35F6	35F7 (no catch)	35F8
34F0	34F1	34F2	34F3	34F4				
	33F1	33F2	33F3	33F4				
32F0	32F1	32F2	32F3					

Table 28 ICES rectangles used in East Anglia LFU

35F0	35F1	35F2
34F0	34F1	34F2
	33F1	33F2
32F0	32F1	32F2
31F0	31F1	31F2

8.4 Predicted SZC impingement effects on shellfish without embedded mitigation measures

The predicted unmitigated SZC impingement effects for the three key crustacean species after adjusting to equivalent adults are given in Table 29. Predicted losses of brown shrimp and brown crab both exceeded the 1% threshold (3.0 % and 2.5 %, respectively). Unmitigated losses of lobsters were < 1 % and are therefore negligible.

Table 29 Annual mean SZC impingement predictions with no impingement mitigation for key shellfish species. Losses have been converted to adult equivalent (EAV) numbers and weights (t) and calculated as a % of the mean international landings (t). Species where the impingement weight > 1 % of the landings – given in bold) are shaded red

Species	Mean SZC	EAV number	EAV weight (t)	Mean landings (t)	% of landings
Brown shrimp	16,072,093	16,072,093	20.89	693	**3.01**
Brown crab	104,284	22,786	11.39	450	**2.53**
Lobster	43	43	0.02	114	**0.01**

8.5 Predicted SZC impingement effects with the LVSE intake heads fitted

Lobsters are not expected to derive any benefit from the proposed LVSE intake head design. Brown crab and brown shrimp would not be able to actively avoid the intake if they were in the water column, but any benefit from the proposed design has not yet been evaluated. Therefore, to be conservative, no benefit from the proposed intake head design has been assumed.

8.6 Predicted SZC impingement effects on shellfish with FRR systems fitted

With the inclusion of the FRR, the impingement losses of those species that exceeded 1 % in the absence of mitigation (brown shrimp and brown crab), were reduced to 0.6 % and 0.6 of landings, respectively (Table 30). The fitting of the FRR systems alone therefore reduces the impingement losses of all three crustacean species to below 1 %. For brown shrimp, losses are regarded as an overestimate, due to the use of an EAV of 1.

8.7 Conclusions on the effects of SZC on shellfish

Four shellfish species (brown crab, European lobster, brown shrimp and whelk were defined as key benthic species on the basis of their socio-economic importance (all four species) and their ecological importance (brown shrimp only). Of these, whelk were absent from the impingement dataset and there is no predicted impingement effects on the species. The predicted losses of the other three shellfish species are less than 1 % of landings. The use of landings as an impingement comparator is highly conservative as SSBs will be larger. As such the predicted SZC effects on all four key shellfish species assessed are considered negligible.

Table 30 Annual mean SZC impingement predictions with FRR mitigation fitted for shellfish species. Losses have been converted to adult equivalent (EAV) numbers and weights (t) and calculated as a % of either the mean international landings (t). Any species where the impingement weight > 1 % of the landings – given in bold) are shaded red

Species	Mean SZC	FRR mortality	EAV number	EAV weight (t)	Mean landings (t)	% of landings
Brown shrimp	16,072,093	3,310,851	3,310,851	4.30	693	**0.62**
Brown crab	104,284	22,608	4,940	2.47	450	**0.55**
Lobster	43	26	26	0.01	114	**0.01**

9 Consideration of climate change effects

Sea temperatures around the UK and Ireland have been warming at between 0.2 and 0.6 °C decade^{-1} over the past 30 years. Projected future changes in the temperature and chemistry of marine waters around the UK and Ireland are having, and will have, effects on the phenology (timing of lifecycle events), productivity and distribution of marine fish and shellfish (Heath *et al*., 2012). In a detailed study of terrestrial birds, butterflies and alpine herbs it was found that these species were undergoing northerly latitudinal change of 6.1 ± 2.4 km decade^{-1} and that there was an advancement of spring events of 2.3 d decade^{-1} (Parmesan and Yohe, 2003). Perry et al. (2005) described that distributions of both exploited and non-exploited North Sea fishes have responded to recent increases in sea temperature, with nearly two-thirds of species shifting in mean latitude or depth or both over 25 years. They found that species with shifting distributions have faster life cycles and smaller body sizes than non-shifting species and that the differential change between species could have consequences for predator-prey relationships. For species that shifted, the mean shift was 99 km northwards in 25y. Dulvy et al. (2008) found that North Sea winter bottom temperature had increased by 1·6 °C over 25 years and that during this period, the whole demersal fish assemblage deepened by ~3·6 m decade$^{–1}$. Simpson et al. (2011) found that most common northeast Atlantic fishes are responding significantly to warming with:

- Three times more species increasing in abundance with warming than declining.
- Local communities are being reorganized despite decadal stability in species composition.
- Species range shifts are the tip of iceberg compared to modification of local communities.

However, the effects of climate change on fish communities are hard to predict with accuracy because behaviour, genetic adaptation, habitat dependency and the impacts of fishing on species result in complex species responses (Heath et al., 2012). Petitgas *et al*., (2013) considered that the key issue for the significance of climate change impact on fishes is habitat availability and connectivity between lifecycle stages with climate driven changes in larval dispersion being a major unknown. Petitgas *et al*., (2013) considered that there was a significant risk for species with strict connectivity between spawning and nursery grounds.

The 2017 Marine Climate Change Impacts Partnership (MCCIP) review on fisheries describes the changes expected in fish and fisheries with climate change (Pinnegar *et al* 2017), and is summarised in this paragraph. There has been a trend in recent decades for warm-affinity species to increase in abundance, and cold-affinity species to decrease in abundance, with many cold-water species moving northwards. For example, there has been a decline in abundance of Atlantic cod (linked with fishing pressure and climate), and a general northwards shift. Mackerel have shown complex changes in recent years, but with a general north and westward shift linked with sea temperature. Sea bass, a warm-affinity species, expanded distribution and increased in numbers in the early 2000s, but fishing mortality then reduced numbers again. Similarly, anchovy has expanded distribution in the North Sea in the past decade. There are exceptions to this general trend, such as sole which has shifted distribution southwards and are able to remain in shallow North Sea waters all year around. Changes in plankton phenology has resulted in changes in timing of fish spawning with a shift of approximately 1.5 weeks earlier per decade in the southern North Sea since 1970s (Pinnegar *et al* 2017).

Modelling predicts that habitat suitability around the UK will increase this century for European squid, sea bass, pilchard, sprat, veined squid, John dory, anchovy, sole, plaice and whiting, and that it will decrease for saithe, hake, red mullet, haddock, halibut, mackerel and herring (Jones, 2013). Except for sole and whiting, the southerly distribution of all species is predicted to move northwards around the UK.

9.1 Changes in the Sizewell fish community

From data collected at the Sizewell A station in the 1980s, it is possible to observe changes in the Greater Sizewell Bay community in the 35+ year period up to the collection of the current SZB CIMP data. SZA impingement estimates in 1981-1982 were compared with those obtained for SZB in the current study. SZA numbers were adjusted for the different pumping capacities (SZA = 30.4 cumecs vs SZB = 51.5 cumecs; ratio ≈1.7), but not for any differences in intake head design.

For several species, the estimated numbers impinged by SZB are significantly higher than those estimated for SZA, even adjusting for pumping capacity (Table 31). For example, seabass at SZB are 194 x more abundant than the SZA estimate, and the species has increased its contribution to the total number of fish impinged from 0.02 % to 4.24 %. Similarly, twaite shad are 8.5 x more abundant in impingement catches now than in the 1980's, and their contribution to the total has increased from 0.003 % to 0.03 %. River lamprey were not recorded in 40 sampling visits at SZA, but between 2009 and 2017, occurred in 33 % of all samples.

Conversely, the abundance of other species has declined. Greater pipefish *Syngnathus acus* were ranked as the 5th most abundant species by Turnpenny and Utting (1987) but in the current dataset, rank only 20th, and estimated numbers have decreased 10-fold (adjusted for pumping capacity). Similarly, Nilsson's pipefish *S. rostellatus* dropped from a rank of 6th to 13th and estimated numbers decreased by a fifth.

Smelt abundance showed little or no change over the 35+ year period, contributing 0.18 % of the total numbers in both datasets. If the relative catching efficiency of the SZA and SZB intake heads for pelagic fish are considered, the smelt abundance may have increased since 1981/82 but the measured difference may also be due to natural variability.

Table 31 Annual estimated numbers of fish impinged by SZA in 1981-1982 (Turnpenny and Utting, 1987) and by SZB in 2009-2017 (BEEMS Technical Report TR339), the number at SZA raised to the SZB pumping capacity, the percentage of the total number impinged and the species' rank

	Sizewell A 1981-1982				**Sizewell B 2009-2017**			
Species	**Number**	**Number (raised)**	**% of total numbers**	**Rank**	**Number**	**% of total numbers**	**Rank**	**Number SZB/SZA**
Seabass	685	1,160	0.02	28	224,719	4.24	4	193.6
European anchovy	240	407	0.01	37	28,849	0.54	8	71.0
River lamprey	0	0	0	-	2,624	0.05	27	-
Twaite shad	98	166	0.003	46	1,407	0.03	37	8.5
Smelt	6,764	11,459	0.18	14	9,320	0.18	18	0.8
Greater pipefish	66,074	111,935	1.77	5	6,485	0.12	20	0.1
Nilsson's pipefish	44,545	75,463	1.19	6	18,850	0.36	13	0.2
Flounder	22,855	38,718	0.61	8	14,912	0.28	14	0.4

9.2 Potential future changes

Some of the key observed trends in the Greater Sizewell Bay are likely to continue:

- Relative changes in species abundance with growing numbers for species that favour warmer water (in winter, in summer or both) and reducing abundance of species near to their southern latitudinal boundary.
- Effects on the phenology of some species (e.g. timing of the arrival of new recruits) and changes in migration patterns as some areas of the North Sea become more or less suitable habitat for each species and/or their prey.
- The presence of large numbers of juvenile species in the Greater Sizewell Bay is dependent upon the connectivity between spawning locations further offshore and their inshore nursery grounds. Some species have a lower tolerance to changes in winter temperatures than to summer temperatures (Dulvy et al., 2008; Perry et al., 2005) and it is possible that winter temperatures will reach a level such that some species may have to abandon fidelity to long established spawning locations which could produce a rapid reduction in the numbers of those species in the southern North Sea but not necessarily in the wider population biomass.

9.3 Effect on SZC impingement predictions

Differences in the two Sizewell impingement datasets show that the fish assemblage off Sizewell is changing due to a combination of climate change, changes in fishing pressure and other anthropogenic causes, both positive and negative (for example, improving water quality in continental rivers is attributed to increases in abundance of twaite shad in European rivers resulting in increases in abundance at Sizewell). SZC will efficiently sample the fish community at Sizewell. If a population increases in abundance then impingement numbers will increase, if a population declines in abundance then impingement numbers will reduce. In such circumstances climate change will have no effect on the predicted negligible effect of SZC impingement on the fish assemblage.

10 Effect of SZC entrapment on the Water Framework Directive (WFD) status of local water bodies

The test for the Water Framework Directive (WFD) compliance assessment is dependent on whether SZC has the potential to cause deterioration in the status of the surface water bodies (both within and between status classes) by adversely affecting biological, hydromorphological and/or physico-chemical quality elements. In principle, SZC entrapment could affect the fish biological quality element of two nearest transitional water bodies to Sizewell:

a. Blyth (S) at approximately 12 km to the north of Sizewell

b. Alde & Ore at approximately 25 km to the south of Sizewell

The United Kingdom Technical Advisory Group for WFD (WFD-UKTAG) has produced an assessment method for fish in transitional water bodies - the Transitional Fish Classification Index (TFCI). (UKTAG 2014). The method is not applicable to coastal water bodies.

The TFCI is a multimetric index composed of 10 individual components known as metrics and listed in Table 32.

Table 32 WFD Transitional Fish Classification Index metrics

Number	Metric	Community characteristic
1	Species composition	Species diversity and composition
2	Presence of indicator species	
3	Species relative abundance	Species abundance
4	Number of taxa that make up 90% of the abundance	
5	Number of estuarine resident taxa (ER)	Nursery function
6	Number of estuarine-dependent marine taxa (MS & MJ)	
7	Functional guild composition	
8	Number of benthic invertebrate feeding taxa	Trophic integrity
9	Number of piscivorous taxa	
10	Feeding guild composition.	

Each metric is assessed by comparing the observed metric values with those expected metric values under reference conditions. A set of reference conditions have been developed for different water body types and sampling gears (the latter does not include power station impingement which provides a much greater sampling efficiency than the alternative net-based sampling methods).

The TFCI is calculated as the sum of all metric scores and converted into an Ecological Quality Ratio (EQR) operating over a range from zero (a severe impact) to one (reference/minimally disturbed). The four class boundaries are:

- High/Good = 0.81
- Good/Moderate = 0.58
- Moderate/Poor = 0.4
- Poor/Bad = 0.2.

With exception of metric 3 in Table 32, all the other metrics are counts of the number of species in functional, feeding or indicator species groups found in the population samples. As described in Section 6.1.2 the fish abundance in the vicinity of Sizewell and in the two transitional water bodies will be subject to considerable in year and between year variability and also variability due to long term trends caused by climate change and changes in fishing pressure due to management action. Measurements of the TFCI will therefore be subject to variability and only developments that have a widescale, very large impact on the community would be expected to make any significant changes to the index. In terms of WFD water body status the following conclusions are pertinent:

a. Marine fish in the transitional waters of the Blyth and Alde Ore are considered to be part of the same stock units as fish at Sizewell and the SZC entrapment effects have been assessed as negligible (Table 18) and much smaller than natural variability in the size of fish populations and would, therefore, be expected to have no effect on the calculated WFD fish biological quality element (Table 32). (SZC would have no effect on freshwater fish in the water bodies).
b. No losses of indicator species are expected due to SZC entrapment
c. There are no predicted significant localised effects of SZC entrapment (Section 7.8.4) and none that would have any significant effect on the calculated WFD fish biological quality element.
d. There are no predicted changes due to SZC entrapment in the number of functional and feeding guilds in the transitional water bodies nor to the number of indicator species.

Given the above, no significant change in the EQR would be expected and certainly none that would result in a change in the WFD status of the Blyth (S) and Alde & Ore transitional water bodies due to SZC entrapment.

Stakeholders have queried whether the effects of smelt entrapment by SZC could affect the WFD status of the Alde Ore. Smelt is found in the Alde Ore and therefore will be one of the indicator species in metric 2 of the TFCI. If the effect of SZC was to totally eliminate smelt from the Alde Ore, there could be a small percentage change in the EQR (dependent upon the existing fish assemblage composition) but whether that would be sufficient to change the water body classification is not clear as we do not have access to the existing TFCI scores (if this calculation has been undertaken for the Alde Ore). The question is then could SZC eliminate smelt from the Alde Ore? For that to occur the majority of estuary population would have to migrate through the impingement risk zone for SZC (i.e. within a few metres of the proposed 4 intakes as a worst case). Given the spatial area available for smelt to migrate through (e.g. a 180-degree hemisphere extending from the Alde Ore estuary mouth) the likelihood of the Alde Ore smelt migrating via a trajectory that only took them to within a few metres of the SZC intakes is considered insignificant. In addition, smelt abundance at Sizewell, as indicated by the SZB impingement data, has no trend from 2009 to 2017 and has apparently not changed since 1981/82 (Section 9.1). Losses due to commercial fishing, which is much greater than that due to SZB, in the 35+ year period have not had any discernible effect on smelt numbers at Sizewell. The size of SZC entrapment losses would be virtually identical to those of SZB (97% of SZB) and the station would sample from the same smelt population. Based upon these considerations it is considered highly unlikely SZC would have any significant effect on the Alde Ore smelt population and certainly not enough to cause the population to collapse. Without such a collapse, the WFD status of the Alde Ore water body would not be affected.

11 Conclusions

Estimates of the number of fish, invertebrates and other individuals impinged by the current SZB station and predictions for the proposed SZC station were based upon 205 samples collected between February 2009 and December 2017. This extensive dataset provides a substantial amount of information on the abundance, seasonality and size structure of individuals impacted by the SZB station.

Ninety-one finfish species were recorded at Sizewell over the 9-year study period. Of these 24 species have been selected as being representative of the assemblage and which include species of importance commercially, ecologically and of conservation value (BEEMS Technical Report TR345), with some species occurring in multiple groups.

Where possible species were compared with defined stock units for that species and compared against internationally coordinated stock assessments. If population data could not be obtained, losses were compared against international landings, which represent only a portion of the total stock biomass. Such assessments are therefore considered highly conservative.

The predicted SZC impingement losses were compared against the negligible effect thresholds derived in Section 6. For some stocks a more precautionary approach was adopted of comparing SZC effects with 1% of a geographically limited subset of the entire stock. In particular, a highly precautionary approach was adopted for European eel whereby the Anglian RBD SSB was used as the stock reference due the uncertainties surrounding both the current eel stock status and its stock dynamics (Sections 6.1.6, 7.6.4). This was equivalent to adopting a negligible effects threshold of approximately 0.005% SSB for the eel stock. This type of precautionary assessment of SZC effects against partial stock estimates has also been applied for twaite shad, allis shad, cucumber smelt and river lamprey

For most key finfish species that will be impinged at SZC, the losses are predicted to be less than the 1 % negligible effect threshold in the absence of impingement mitigation. However, in the absence of mitigation losses of seabass, thin-lipped grey mullet and European eel were greater than 1 %. In addition, losses of brown shrimp and brown crab were greater than 1 % when compared with landings.

When the effects of the proposed LVSE intake heads and FRR systems at SZC are considered, the losses of all species are predicted to be below the 1 % negligible effects screening threshold when compared against the relevant population or landings estimates.

The individual entrainment and impingement impacts are such that when combined into a single entrapment estimate, there is very little difference to the overall conclusions that are reached when each is viewed separately. In the absence of mitigation, species that exceed the 1 % threshold are bass, thin-lipped grey mullet, European eels and sand gobies. With the proposed impingement mitigation fitted, the only species that remains above the 1 % threshold is the sand goby (entrainment = 1.4 % of abundance; impingement = 0.0 %; entrapment = 1.4 %).

Sand gobies are a highly, short-lived genus. Given that the species is not commercially-exploited, it is considered that losses of 10 % are a more appropriate negligible effects threshold (as discussed in Section 6.1). Therefore, losses of 1.4 % of total abundance by SZC are regarded as negligible.

It is therefore concluded that the proposed SZC station with FRR systems and LVSE intake heads fitted will result in negligible entrapment losses of all 24 key finfish taxa and 4 shellfish taxa.

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Appendix A Cooling water system design

The cooling water system for SZC will essentially be the same as for HPC. (There will be detailed differences for example in the layout of the FRR system, the need or not for an Archimedes screw but none of these will affect the calculations in this report). The key design features are:

a. the total cooling water abstraction at SZC will be approximately 131.86 cumecs with a maximum of 9% of the total cooling water flow supplying the essential and auxiliary cooling water systems via band screens and the remaining 91% (120 cumecs) supplying the main cooling water systems (CRF) via the station drum screens.

b. the SZC band screens will be fitted with their own FRR systems

c. the trash rack bar spacing for SZC will be 75 mm. The SZC trash rack will have a rake which returns impinged materials (including fish) to the FRR system.

d. the SZC FRR system will not be chlorinated unless there is a major change in the future water quality conditions that would facilitate the rapid growth of biofouling organisms but this is considered unlikely.

A.1 Main cooling water systems in each pumping station

SZC will consist of two EPR units. Each unit has its own forebay, pumping station, debris recovery building (HCB) and discharge pond. Each pumping station is divided into four distinct sectors: two central sectors (four channels (or ‘trains’) each) with high flow volume drum screens (ds2 and ds3) and two lateral sectors (one channel (or ‘train’) each) with lower flow volume band screens (bs1 and bs4).

Each pumping station supplies seawater to a number of systems; the main ones of which are:

CRF:	Cooling Water System used to extract waste heat from the turbine steam condensers.
SEC:	Essential Cooling Water system (Nuclear Island)
SEN:	Auxiliary Cooling Water system (Conventional Island)
SRU:	Ultimate cooling water system (Emergency use only)
CFI:	Circulating Water Filtration system: supplies wash water for the drum and band screens.

The schematic layout of each pump station is shown in Figure 12.

At Mean Sea Level (MSL) the system flow rates per unit are as follows:

CRF	2*30 cumecs per unit (supplied from the 2 drum screens in each pump station)
SEC	2*1.2 cumecs per unit (can be supplied from the drum screens or band screens in any combination)
SEN	2*1.61 cumecs per unit (normally supplied from the 2 band screens in each pump station)
SRU	Negligible flow (only used when testing the system or in emergency)
CFI	additional to SEC flow consisting of 2*0.117 cumecs for the 2 drum screens and a worst case of 2*0.039 cumecs for the 2 band screens.

As the SEC/CFI seawater sources can be from the drum screens or band screens there is a range of different water flows through the different filtration systems at SZC.

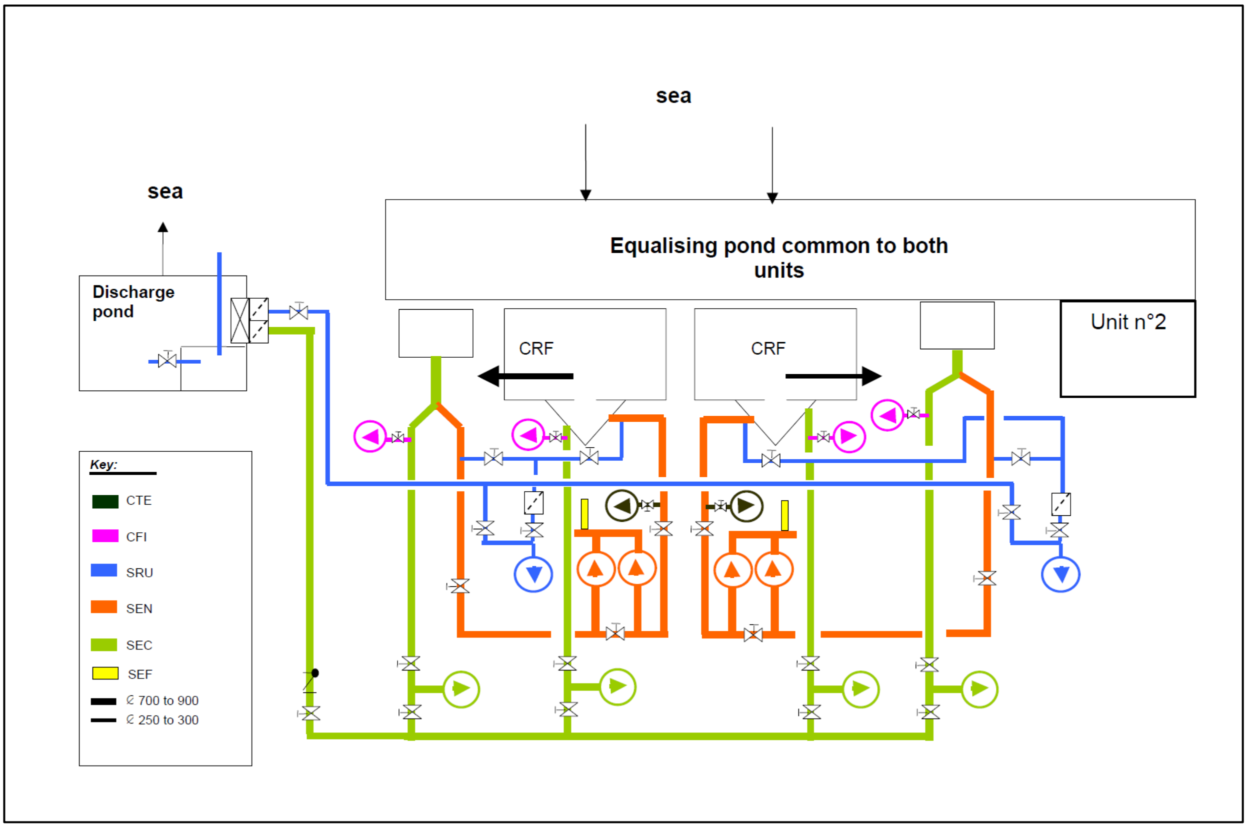


Figure 12 Illustrative schematic of EPR cooling water circuits for each unit (Source EDF CNEPE E.T.DOMA/09 0119 A1 Approved). The equalising pond shown in the figure is the station forebay and SZC has 1 forebay for each unit

Table 33 details the minimum flow at MSL (mean sea level) through the drum screens and Table 34 shows the maximum flow through the drum screens at MSL. Dependent upon the system configuration the seawater flow through the band screens can, therefore, vary between 4.9% and 9% of the total seawater abstraction of 131.86 cumecs.

Table 33 Cooling water flow volumes when SEC/CFI systems are supplied from the band screens

	Channel	flow (cumecs)	Flow through	cumecs		cumecs
	bs1	2.966	drum screens	60		
	ds2	30	band screens	5.932		
	ds3	30	Total CW flow	65.932	of which CRF	60
	bs4	2.966				
Total flow/EPR		65.932				
	2 EPRs	131.86	Flow through drum screens			120
			Total CW flow			131.86
			Band screen flow as % of total flow			**9.0%**

Table 34 Cooling water flow volumes when SEC/CFI systems are supplied from the drum screens

	Channel	flow (cumecs)	Flow through	cumecs		cumecs
	bs1	1.61	drum screens	62.712		
	ds2	31.356	band screens	3.22		
	ds3	31.356	total CW flow	65.932	of which CRF	60
	bs4	1.61				
Total flow/EPR		65.932				
	2 EPRs	131.86	Flow through drum screens			125.42
			Total CW flow			**131.86**
			Band screen flow as % of total flow			**4.9%**

Appendix B Calculated annual impingement by number 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. Colour-coding indicates the 24 key finfish species in the Greater Sizewell Bay (BEEMS Technical Report TR345) and the type of model that was used to estimate impingement numbers for each species.

Key species
Zero-Inflated Negative Binomial with two factors for Month and Year
Zero-Inflated Negative Binomial with two factors for Sixth (2 months) and Year
Zero-Inflated Negative Binomial with two factors for Quarter and Year
Negative Binomial with one factor for Month
Species where the model did not converge

			SZB - estimate			**SZC - prediction**		
	Common name	**Scientific name**	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**
	Finfish							
1	Sprat	*Sprattus sprattus*	2,782,934	1,089,329	7,110,821	7,125,393	2,789,105	18,206,464
2	Herring	*Clupea harengus*	998,201	109,735	9,081,550	2,555,783	280,965	23,252,294
3	Whiting	*Merlangius merlangus*	728,597	178,790	2,969,271	1,865,492	457,773	7,602,486
4	European seabass	*Dicentrarchus labrax*	224,719	61,132	826,468	575,367	156,523	2,116,078
5	Sand gobies	*Pomatoschistus spp*	149,045	40,410	549,860	381,612	103,464	1,407,855
6	Dover sole	*Solea solea*	97,665	39,070	244,218	250,059	100,033	625,293
7	Dab	*Limanda limanda*	58,163	8,659	390,758	148,921	22,171	1,000,493
8	European anchovy	*Engraulis encrasicolus*	28,849	4,627	180,746	73,865	11,847	462,780
9	Thin-lipped grey mullet	*Liza ramada*	26,435	578	1,209,172	67,684	1,480	3,095,949
10	Lesser weever fish	*Echiichthys (trachinus) vipera*	20,728	8,605	50,050	53,072	22,032	128,148
11	Bib	*Trisopterus luscus*	20,054	4,152	96,904	51,345	10,630	248,112
12	Transparent goby	*Aphia minuta*	19,207	2,535	156,592	49,176	6,490	400,937

			SZB - estimate			SZC - prediction		
	Common name	**Scientific name**	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**
13	Nilsson's pipefish	*Syngnathus rostellatus*	18,850	5,558	64,273	48,263	14,232	164,564
14	Flounder	*Platichthys flesus*	14,912	6,298	35,319	38,180	16,125	90,431
15	Pogge (hooknose)	*Agonus cataphractus*	12,622	3,644	43,731	32,317	9,330	111,968
16	Five-bearded rockling	*Ciliata mustela*	10,586	3,600	31,175	27,103	9,218	79,820
17	European plaice	*Pleuronectes platessa*	9,877	3,306	29,540	25,288	8,464	75,633
18	Cucumber smelt	*Osmerus eperlanus*	9,320	3,216	27,101	23,863	8,233	69,389
19	Atlantic cod	*Gadus morhua*	6,579	1,678	26,056	16,845	4,297	66,715
20	Great pipefish	*Syngnathus acus*	6,485	1,644	25,599	16,605	4,209	65,544
21	Lesser spotted dogfish	*Scyliorhinus canicula*	5,184	532	50,717	13,273	1,363	129,855
22	Common sea snail	*Liparis liparis*	4,893	2,528	9,820	12,528	6,473	25,143
23	Common dragonet	*Callionymus lyra*						
24	Thornback ray	*Raja clavata*	4,219	1,185	15,492	10,802	3,034	39,665
25	Tub gurnard	*Trigla (chelidonichthys) lucerna*	3,518	1,065	12,055	9,009	2,726	30,865
26	Common sandeel	*Ammodytes tobianus*	3,175	1,366	7,547	8,128	-	-
27	River lamprey	*Lampetra fluviatilis*	2,624	929	7,935	6,720	2,378	20,316
28	Grey mullets	*Mugilidae*	2,556	2,335	2,826	6,545	5,979	7,235
29	Scald fish	*Arnoglossus laterna*	2,393	906	7,635	6,126	2,321	19,548
30	Pilchard	*Sardina pilchardus*	2,037	399	11,884	5,216	1,021	30,428
31	Starry smooth hound	*Mustelus asterias*	1,869	109	55,020	4,785	278	140,872
32	Bullrout	*Myoxocephalus scorpius*	1,824	388	9,225	4,671	994	23,619
33	Three-spined stickleback	*Gasterosteus aculeatus*	1,810	400	8,339	4,633	1,025	21,351
34	European eel	*Anguilla anguilla*	1,764	714	5,015	4,516	1,828	12,841
35	Horse-mackerel	*Trachurus trachurus*	1,592	312	11,890	4,077	800	30,442
36	Lemon sole	*Microstomus kitt*	1,563	210	12,993	4,001	538	33,267
37	Twaite shad	*Alosa fallax*	1,407	224	9,275	3,601	575	23,747
38	Poor cod	*Trisopterus minutus*	1,109	37	36,200	2,840	95	92,686
39	Sea scorpion	*Taurulus bubalis*	979	328	3,009	2,507	840	7,703
40	Tompot blenny	*Parablennius gattorugine*						
41	Brill	*Scophthalmus rhombus*	705	47	56,049	1,805	120	143,506
42	Black goby	*Gobius niger*	703	172	2,938	1,799	440	7,521
43	Solenette	*Buglossidium luteum*	646	171	3,435	1,654	437	8,796

			SZB - estimate			SZC - prediction		
	Common name	**Scientific name**	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**
44	Butter fish	*Pholis gunnellus*	636	363	1,125	1,628	929	2,879
45	Snake pipefish	*Entelurus aequoreus*	634	161	2,533	1,623	412	6,485
46	Sand Smelt	*Atherina boyeri*	595	33	11,255	1,523	85	28,817
47	Great sandeel	*Hyperoplus lanceolatus*	570	44	7,434	1,459	112	19,034
48	Rock goby	*Gobius paganellus*	458	354	641	1,171	908	1,642
49	Witch	*Glyptocephalus cynoglossus*	290	5	15,990	743	14	40,941
50	Mackerel	*Scomber scombrus*	245	180	352	628	460	900
51	Red mullet	*Mullus surmuletus*	186	59	613	476	150	1,569
52	Montague's seasnail	*Liparis montagui*						
53	Garfish	*Belone belone*	80	17	396	206	42	1,015
54	Grey gurnard	*Eutrigla (chelidonicthys) gurnardus*	76	10	568	193	26	1,455
55	Turbot	*Scophthalmus maximus (Psetta maxima)*	66	10	438	169	26	1,122
56	Frie's goby	*Lesueurigobius friesii*	56	34	103	144	87	263
57	Lesser forkbeard (tadpolefish)	*Raniceps raninus*	48	23	114	122	58	291
58	Corkwing wrasse	*Crenilabrus melops*	48	22	114	122	57	292
59	John dory	*Zeus faber*	44	20	102	113	51	261
60	Sand smelt	*Atherina presbyter*	41	21	97	106	54	247
61	Northern rockling	*Ciliata septentrionalis*	37	19	78	95	48	200
62	Ballan wrasse	*Labrus bergylta*	28	11	85	71	29	217
63	Tope	*Galeorhinus galeus*	25	12	51	64	31	132
64	Four-bearded rockling	*Enchelyopus cimbrius*	25	10	73	63	24	188
65	Saithe	*Pollachius virens*	23	13	41	59	33	104
66	Lumpsucker	*Cyclopterus lumpus*	22	7	84	56	18	215
67	Spotted ray	*Raja montagui*	22	10	48	55	26	124
68	Sandeel	*Ammodytes marinus*	17	7	41	44	18	104
69	Crystal goby	*Crystallogobius linearis*	17	9	32	44	23	83
70	Thick-lipped grey mullet	*Crenimugil labrosus*	17	8	35	43	21	90
71	Norway bullhead	*Micrenophrys lilljeborgii*	15	6	44	39	16	112
72	Black seabream	*Spondyliosoma cantharus*	13	6	30	33	15	76
73	Cuckoo wrasse	*Labrus mixtus*	9	4	22	24	10	57
74	Bigeye rockling	*Antonogadus macropthalmus*	9	2	43	22	5	110

			SZB - estimate			**SZC - prediction**		
	Common name	**Scientific name**	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**
75	Deep-snouted pipefish	*Syngnathus typhle*	7	3	18	18	8	45
76	Goldsinny	*Ctenolabrus rupestris*	6	2	16	15	6	40
77	Snake blenny	*Lumpenus lampretaeformis*	6	2	16	15	6	40
78	Norway pout	*Trisopterus esmarkii*	5	1	19	12	3	49
79	Red gurnard	*Aspitrigla (chelidonichthys) cuculus*	4	1	18	10	2	47
80	Sea Trout	*Salmo trutta*	4	1	15	10	2	37
81	Shore rockling	*Gaidropsarus mediterraneus*	3	1	27	9	2	68
82	Sand sole	*Pegusa lascaris*	2	0	13	6	1	34
83	Allis shad	*Alosa alosa*	2	0	13	5	1	33
84	Sea lamprey	*Petromyzon marinus*	2	0	13	5	1	33
85	Spotted dragonet	*Callionymus maculatus*	2	0	11	4	1	27
86	Pollack	*Pollachius pollachius*	2	0	11	4	1	27
87	Eelpout (Viviparous blenny)	*Zoarces viviparous*	‘-	‘-	‘-	‘-	‘-	‘-
88	Sandeels	*Ammodytidae*	‘-	‘-	‘-	‘-	‘-	‘-
89	Jeffrey's goby	*Buenia jeffreysii*	‘-	‘-	‘-	‘-	‘-	‘-
90	Unidentified herrings	*Clupeidae*	‘-	‘-	‘-	‘-	‘-	‘-
91	Baillons wrasse	*Symphodus (crenilabrus) balloni*	‘-	‘-	‘-	‘-	‘-	‘-
	Invertebrates							
1	Ctenophores		50,900,460	16,324,772	162,596,067	130,324,945	41,797,756	416,309,076
2	Brown shrimp	*Crangon crangon*	6,277,209	3,296,740	11,966,573	16,072,093	8,440,934	30,639,073
3	Pink shrimp	*Pandalus montagui*	1,168,116	636,333	2,148,927	2,990,831	1,629,259	5,502,088
4	Common prawn	*Palaemon serratus*	952,055	154,445	5,869,354	2,437,631	395,440	15,027,824
5	Common swimming crab	*Polybius (liocarcinus) holsatus*	438,873	81,506	2,363,663	1,123,684	208,686	6,051,895
6		*Crangon allmanni*	432,361	69,659	2,693,635	1,107,012	178,354	6,896,751
7	Plumose anemone	*Metridium senile*	218,034	106,691	450,021	558,251	273,170	1,152,229
8	Dahlia anemone	*Urticina (tealia) felina*	73,661	29,573	184,397	188,600	75,718	472,128
9	Jellyfish		69,056	10	560,031,984	176,809	26	1,433,899,368
10	Isopod	Idoteidae	62,363	8,605	463,125	159,675	22,032	1,185,779
11	Edible crab	*Cancer pagurus*	40,730	8,556	193,949	104,284	21,906	496,584
12	Little cuttlefish	*Sepiola atlantica*	32,680	22,566	47,862	83,674	57,779	122,545

	Common name	Scientific name	SZB - estimate			SZC - prediction		
			Mean	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**
13	Ragworms	*Nereis* spp.	20,243	6,658	75,351	51,829	17,046	192,928
14	Green shore crab	*Carcinus maenas*	19,866	4,951	79,943	50,864	12,676	204,684
15	Velvet swimming crab	*Necora puber*	18,650	958	364,060	47,751	2,453	932,134
16	Unidentified spider crab	Macropodia spp	16,148	1,904	140,715	41,346	4,875	360,285
17	European common squid	*Loligo (alloteuthis) subulata*	13,960	8,071	24,849	35,744	20,664	63,623
18	Edible mussel	*Mytilus edulis*	13,933	12,967	3.59 x 10^{122}	35,674	33,202	9.18 x 10^{122}
19	Long-leg spider crab	*Macropodia rostrata*	9,999	1,406	72,015	25,602	3,600	184,387
20	Scaleworms		9,339	3,037	29,522	23,911	7,775	75,587
21	Hairy crab	*Pilumnus hirtellus*	6,649	74	603,010	17,025	189	1,543,940
22	Anemone unidentified	Anemone unidentified	5,282	4,666	6,006	13,524	11,946	15,379
23	Common starfish	*Asterias rubens*	4,776	120	189,514	12,229	308	485,231
24	Lug-worm	*Arenicola marina*	1,888	149	25,723	4,833	381	65,861
25	Sea slugs	Nudibranchia	1,209	24	67,265	3,096	61	172,223
26	Beadlet anemone	*Actinia equina*	667	501	915	1,708	1,281	2,344
27	Unidentified sea urchin		618	525	733	1,581	1,345	1,877
28	Hermit crab	*Eupagurus bernhardus*	578	485	724	1,479	1,242	1,855
29		*Processa canaliculata*	563	428	758	1,442	1,097	1,941
30		*Psammechinus miliaris*	515	357	796	1,318	914	2,039
31	Xanthidae	Xanthid crab	62	27	148	159	69	379
32	European squid	*Loligo vulgaris*	59	42	83	152	107	214
33	Northern squid	*Loligo forbesi*	45	27	78	116	70	199
34	Necklace shell	*Euspira (polinices) catena*	35	20	61	90	52	156
35	Bristle worms	Polychaeta	35	17	73	88	42	186
36		Processidae	27	14	55	69	36	141
37		*Upogebia deltaura*	21	8	55	53	20	141
38		*Ophiura ophiura*	17	6	46	44	16	117
39	Lobster	*Homarus gammarus*	17	6	58	43	15	149
40		Gammaridae	12	3	48	31	8	123
41	Purple heart urchin	*Spatangus purpureus*	11	4	30	29	11	77
42	Sea cucumbers	Holothuroidea	7	1	50	18	2	127
43	Cuttle-fish	*Sepia elegans*	5	1	37	13	2	94

	Common name	Scientific name	SZB - estimate			SZC - prediction		
			Mean	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**
44		*Axius stirhynchus*	2	1	14	6	2	36
45	Unidentified swimming crab	*Liocarcinus* spp.	2	0	13	6	1	34
46	Great spider crab	*Hyas araneus*	‘-	‘-	‘-	‘-	‘-	‘-
47	Contracted crab	*Hyas coarctatus*	‘-	‘-	‘-	‘-	‘-	‘-
48	Swimming crab	*Liocarcinus depurator*	‘-	‘-	‘-	‘-	‘-	‘-
49	Marbled swimming crab	*Liocarcinus marmoreus*	‘-	‘-	‘-	‘-	‘-	‘-
50	Dwarf-swimming crab	*Liocarcinus pusillus*	‘-	‘-	‘-	‘-	‘-	‘-
51	Ghost shrimp	*Pasiphaea sivado*	‘-	‘-	‘-	‘-	‘-	‘-
52	Hairy crab	*Pilumnus spinifer*	‘-	‘-	‘-	‘-	‘-	‘-
53	Common cuttlefish	*Sepia officinalis*	‘-	‘-	‘-	‘-	‘-	‘-
54	Unidentified brittlestar		‘-	‘-	‘-	‘-	‘-	‘-
55		*Bolocera tuediae*	‘-	‘-	‘-	‘-	‘-	‘-
56	Crangonid (brown) shrimps	Crangonidae	‘-	‘-	‘-	‘-	‘-	‘-
57	Scorpion spider crab	*Inachus dorsettensis*	‘-	‘-	‘-	‘-	‘-	‘-
58	Slender spider crab	*Macropodia tenuirostris*	‘-	‘-	‘-	‘-	‘-	‘-
59	Spider crabs	Majidae	‘-	‘-	‘-	‘-	‘-	‘-
60	Opossum shrimps	Mysidacea	‘-	‘-	‘-	‘-	‘-	‘-
61	Long clawed porcelain crab	*Pisidia longgicornis*	‘-	‘-	‘-	‘-	‘-	‘-
62	Rissos crab	*Xantho pilipes*	‘-	‘-	‘-	‘-	‘-	‘-

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

C.1 Predicted impingement without embedded mitigation measures

	Annually raised SZB estimate			Annually raised SZC prediction			EAV equivalent numbers		
Species	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**
Sprat	2,782,934	1,089,329	7,110,821	7,125,393	2,789,105	18,206,464	5,352,978	2,095,325	13,677,673
Herring	998,201	109,735	9,081,550	2,555,783	280,965	23,252,294	1,827,944	200,951	16,630,477
Whiting	728,597	178,790	2,969,271	1,865,492	457,773	7,602,486	664,261	163,003	2,707,077
Bass	224,719	61,132	826,468	575,367	156,523	2,116,078	128,861	35,055	473,921
Sand goby	149,045	40,410	549,860	381,612	103,464	1,407,855	381,612	103,464	1,407,855
Sole	97,665	39,070	244,218	250,059	100,033	625,293	53,233	21,295	133,113
Dab	58,163	8,659	390,758	148,921	22,171	1,000,493	66,211	9,857	444,827
Anchovy	28,849	4,627	180,746	73,865	11,847	462,780	71,952	11,540	450,798
Thin-lipped grey mullet	26,435	578	1,209,172	67,684	1,480	3,095,949	5,642	123	258,069
Flounder	14,912	6,298	35,319	38,180	16,125	90,431	17,631	7,446	41,759
Plaice	9,877	3,306	29,540	25,288	8,464	75,633	8,734	2,923	26,122
Smelt	9,320	3,216	27,101	23,863	8,233	69,389	18,170	6,269	52,834
Cod	6,579	1,678	26,056	16,845	4,297	66,715	6,049	1,543	23,958
Thornback ray	4,219	1,185	15,492	10,802	3,034	39,665	2,082	585	7,646
River lamprey	2,624	929	7,935	6,720	2,378	20,316	6,720	2,378	20,316
Eel	1,764	714	5,015	4,516	1,828	12,841	4,516	1,828	12,841
Twaite shad	1,407	224	9,275	3,601	575	23,747	3,601	575	23,747
Horse mackerel	1,592	312	11,890	4,077	800	30,442	4,077	800	30,442
Mackerel	245	180	352	628	460	900	628	460	900
Tope	25	12	51	64	31	132	64	31	132
Sea trout	4	1	15	10	2	37	10	2	37
Allis shad	2	0	13	5	1	33	5	1	33
Sea lamprey	2	0	13	5	1	33	5	1	33
Salmon	0	0	0	0	0	0	0	0	0

	EAV equivalent weight (t)				EAV weight as % of SSB			Mean landings (t)	EAV weight as % of landings		
Species	**Mean**	**Lower**	**Upper**	**Mean SSB (t)**	**Mean**	**Lower**	**Upper**		**Mean**	**Lower**	**Upper**
Sprat	56.2	22.0	143.7	220,757	**0.03**	**0.01**	**0.07**	151,322	0.04	0.01	0.09
Herring	344.9	37.9	3,137.6	2,198,449	**0.02**	**0.00**	**0.14**	400,244	0.09	0.01	0.78
Whiting	189.9	46.6	773.7	151,881	**0.13**	**0.03**	**0.51**	17,570	1.08	0.27	4.40
Bass	197.3	53.7	725.5	14,897	**1.32**	**0.36**	**4.87**	3,051	6.47	1.76	23.78
Sand goby	0.7	0.2	2.7	205,882,353	**0.19**	**0.05**	**0.68**	NA	NA	NA	NA
Sole	11.4	4.6	28.5	43,770	**0.03**	**0.01**	**0.07**	12,800	0.09	0.04	0.22
Dab	2.7	0.4	18.2	NA	NA	NA	NA	6,135	**0.04**	**0.01**	**0.30**
Anchovy	1.5	0.2	9.4	NA	NA	NA	NA	1,625	**0.09**	**0.01**	**0.58**
Thin-lipped grey mullet	2.9	0.1	134.2	NA	NA	NA	NA	120	**2.45**	**0.05**	**111.90**
Flounder	1.4	0.6	3.4	NA	NA	NA	NA	2,309	**0.06**	**0.03**	**0.15**
Plaice	2.1	0.7	6.4	690,912	**0.00**	**0.00**	**0.00**	80,367	0.00	0.00	0.01
Smelt	0.3	0.1	0.9	105,733,825	**0.02**	**0.01**	**0.05**	8	3.56	1.23	10.36
Cod	15.7	4.0	62.3	103,025	**0.02**	**0.00**	**0.06**	34,701	0.05	0.01	0.18
Thornback ray	6.6	1.9	24.4	NA	NA	NA	NA	1,573	**0.42**	**0.12**	**1.55**
River lamprey	0.4	0.1	1.6	62	**0.86**	**0.30**	**2.59**	1	47.65	16.86	144.07
Eel	1.5	0.6	4.2	79	**1.89**	**0.76**	**5.37**	14	10.70	4.33	30.41
Twaite shad	1.1	0.2	7.4	7,519,986	**0.05**	**0.01**	**0.32**	1	84.60	13.50	557.82
Horse mackerel	0.6	0.1	4.3	NA	NA	NA	NA	20,798	**0.00**	**0.00**	**0.02**
Mackerel	0.2	0.1	0.3	3,888,854	**0.00**	**0.00**	**0.00**	1,026,828	0.00	0.00	0.00
Tope	0.4	0.2	0.9	NA	NA	NA	NA	498	**0.09**	**0.04**	**0.18**
Sea trout	0.0	0.0	0.1	NA	NA	NA	NA	39,795	**0.02**	**0.01**	**0.09**
Allis shad	0.0	0.0	0.0	27,397	0.02	0.00	0.12	0.2	**1.79**	**0.30**	**12.50**
Sea lamprey	0.0	0.0	0.0	NA	NA	NA	NA	NA	NA	NA	NA
Salmon	0.0	0.0	0.0	NA	NA	NA	NA	38,456	**0.00**	**0.00**	**0.00**

C.2 Predicted SZC impingement with the effect of LVSE intake heads

	Annually raised SZB estimate			**Annually raised SZC estimate**			**Intake head mortality**			**EAV equivalent numbers**		
Species	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**
Sprat	2,782,934	1,089,329	7,110,821	7,125,393	2,789,105	18,206,464	2,729,025	1,068,227	6,973,076	2,050,190	802,510	5,238,549
Herring	998,201	109,735	9,081,550	2,555,783	280,965	23,252,294	978,865	107,610	8,905,629	700,103	76,964	6,369,473
Whiting	728,597	178,790	2,969,271	1,865,492	457,773	7,602,486	714,484	175,327	2,911,752	254,412	62,430	1,036,811
Bass	224,719	61,132	826,468	575,367	156,523	2,116,078	220,366	59,948	810,458	49,354	13,426	181,512
Sand goby	149,045	40,410	549,860	381,612	103,464	1,407,855	146,157	39,627	539,208	146,157	39,627	539,208
Sole	97,665	39,070	244,218	250,059	100,033	625,293	95,773	38,313	239,487	20,388	8,156	50,982
Dab	58,163	8,659	390,758	148,921	22,171	1,000,493	57,037	8,491	383,189	25,359	3,775	170,369
Anchovy	28,849	4,627	180,746	73,865	11,847	462,780	28,290	4,537	177,245	27,558	4,420	172,656
Thin-lipped grey mullet	26,435	578	1,209,172	67,684	1,480	3,095,949	25,923	567	1,185,748	2,161	47	98,840
Flounder	14,912	6,298	35,319	38,180	16,125	90,431	14,623	6,176	34,635	6,753	2,852	15,994
Plaice	9,877	3,306	29,540	25,288	8,464	75,633	9,685	3,242	28,967	3,345	1,120	10,005
Smelt	9,320	3,216	27,101	23,863	8,233	69,389	9,139	3,153	26,576	6,959	2,401	20,236
Cod	6,579	1,678	26,056	16,845	4,297	66,715	6,451	1,646	25,552	2,317	591	9,176
Thornback ray	4,219	1,185	15,492	10,802	3,034	39,665	4,137	1,162	15,192	797	224	2,928
River lamprey	2,624	929	7,935	6,720	2,378	20,316	2,574	911	7,781	2,574	911	7,781
Eel	1,764	714	5,015	4,516	1,828	12,841	1,730	700	4,918	1,730	700	4,918
Twaite shad	1,407	224	9,275	3,601	575	23,747	1,379	220	9,095	1,379	220	9,095
Horse mackerel	1,592	312	11,890	4,077	800	30,442	1,561	306	11,659	1,561	306	11,659
Mackerel	245	180	352	628	460	900	241	176	345	241	176	345
Tope	25	12	51	64	31	132	24	12	50	24	12	50
Sea trout	4	1	15	10	2	37	4	1	14	4	1	14
Allis shad	2	0	13	5	1	33	2	0	13	2	0	13
Sea lamprey	2	0	13	5	1	33	2	0	13	2	0	13
Salmon	0	0	0	0	0	0	0	0	0	0	0	0

	EAV equivalent weight (t)			**Mean SSB (t)**	**EAV weight as % of SSB**			**Mean landings (t)**	**EAV weight as % of landings**		
Species	**Mean**	**Lower**	**Upper**		**Mean**	**Lower**	**Upper**		**Mean**	**Lower**	**Upper**
Sprat	21.5	8.4	55.0	220,757	**0.01**	**0.00**	**0.02**	151,322	0.01	0.01	0.04
Herring	132.1	14.5	1,201.7	2,198,449	**0.01**	**0.00**	**0.05**	400,244	0.03	0.00	0.30
Whiting	72.7	17.8	296.3	151,881	**0.05**	**0.01**	**0.20**	17,570	0.41	0.10	1.69
Bass	75.6	20.6	277.9	14,897	**0.51**	**0.14**	**1.87**	3,051	2.48	0.67	9.11
Sand goby	0.3	0.1	1.0	205,882,353	**0.07**	**0.02**	**0.26**	NA	NA	NA	NA
Sole	4.4	1.7	10.9	43,770	**0.01**	**0.00**	**0.02**	12,800	0.03	0.01	0.09
Dab	1.0	0.2	7.0	NA	NA	NA	NA	6,135	**0.02**	**0.00**	**0.11**
Anchovy	0.6	0.1	3.6	NA	NA	NA	NA	1,625	**0.04**	**0.01**	**0.22**
Thin-lipped grey mullet	1.1	0.0	51.4	NA	NA	NA	NA	120	**0.94**	**0.02**	**42.86**
Flounder	0.6	0.2	1.3	NA	NA	NA	NA	2,309	**0.02**	**0.01**	**0.06**
Plaice	0.8	0.3	2.5	690,912	**0.00**	**0.00**	**0.00**	80,367	0.00	0.00	0.00
Smelt	0.1	0.0	0.3	105,733,825	**0.01**	**0.00**	**0.02**	8	1.36	0.47	3.97
Cod	6.0	1.5	23.9	103,025	**0.01**	**0.00**	**0.02**	34,701	0.02	0.00	0.07
Thornback ray	2.5	0.7	9.4	NA	NA	NA	NA	1,573	**0.16**	**0.05**	**0.59**
River lamprey	0.2	0.1	0.6	62	**0.33**	**0.12**	**0.99**	1	18.25	6.46	55.18
Eel	0.6	0.2	1.6	79	**0.72**	**0.29**	**2.06**	14	4.10	1.66	11.65
Twaite shad	0.4	0.1	2.8	7,519,986	**0.02**	**0.00**	**0.12**	1	32.40	5.17	213.64
Horse mackerel	0.2	0.0	1.6	NA	NA	NA	NA	20,798	**0.00**	**0.00**	**0.01**
Mackerel	0.1	0.1	0.1	3,888,854	**0.00**	**0.00**	**0.00**	1,026,828	0.00	0.00	0.00
Tope	0.2	0.1	0.3	NA	NA	NA	NA	498	**0.03**	**0.02**	**0.07**
Sea trout	0.0	0.0	0.0	NA	NA	NA	NA	39,795	**0.01**	**0.00**	**0.04**
Allis shad	0.0	0.0	0.0	27,397	**0.01**	**0.00**	**0.05**	0.2	0.68	0.11	4.79
Sea lamprey	0.0	0.0	0.0	NA	NA	NA	NA	NA	NA	NA	NA
Salmon	0.0	0.0	0.0	NA	NA	NA	NA	38,456	**0.00**	**0.00**	**0.00**

C.3 Predicted SZC impingement with FRR systems fitted

	Annually raised SZB estimate			Annually raised SZC estimate			FRR mortality			EAV equivalent numbers		
Species	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**
Sprat	2,782,934	1,089,329	7,110,821	7,125,393	2,789,105	18,206,464	7,125,393	2,789,105	18,206,464	5,352,978	2,095,325	13,677,673
Herring	998,201	109,735	9,081,550	2,555,783	280,965	23,252,294	2,555,783	280,965	23,252,294	1,827,944	200,951	16,630,477
Whiting	728,597	178,790	2,969,271	1,865,492	457,773	7,602,486	1,026,879	251,986	4,184,864	365,649	89,727	1,490,138
Bass	224,719	61,132	826,468	575,367	156,523	2,116,078	317,979	86,503	1,169,457	71,215	19,373	261,914
Sand goby	149,045	40,410	549,860	381,612	103,464	1,407,855	78,612	21,314	290,018	78,612	21,314	290,018
Sole	97,665	39,070	244,218	250,059	100,033	625,293	53,392	21,359	133,510	11,366	4,547	28,422
Dab	58,163	8,659	390,758	148,921	22,171	1,000,493	33,622	5,005	225,880	14,948	2,225	100,428
Anchovy	28,849	4,627	180,746	73,865	11,847	462,780	73,865	11,847	462,780	71,952	11,540	450,798
Thin-lipped grey mullet	26,435	578	1,209,172	67,684	1,480	3,095,949	37,266	815	1,704,591	3,106	68	142,090
Flounder	14,912	6,298	35,319	38,180	16,125	90,431	14,440	6,099	34,202	6,668	2,816	15,794
Plaice	9,877	3,306	29,540	25,288	8,464	75,633	5,680	1,901	16,989	1,962	657	5,868
Smelt	9,320	3,216	27,101	23,863	8,233	69,389	23,863	8,233	69,389	18,170	6,269	52,834
Cod	6,579	1,678	26,056	16,845	4,297	66,715	10,607	2,706	42,010	3,809	972	15,086
Thornback ray	4,219	1,185	15,492	10,802	3,034	39,665	2,277	639	8,361	439	123	1,612
River lamprey	2,624	929	7,935	6,720	2,378	20,316	1,384	490	4,185	1,384	490	4,185
Eel	1,764	714	5,015	4,516	1,828	12,841	982	398	2,793	982	398	2,793
Twaite shad	1,407	224	9,275	3,601	575	23,747	3,601	575	23,747	3,601	575	23,747
Horse mackerel	1,592	312	11,890	4,077	800	30,442	4,077	800	30,442	4,077	800	30,442
Mackerel	245	180	352	628	460	900	628	460	900	628	460	900
Tope	25	12	51	64	31	132	39	19	79	39	19	79
Sea trout	4	1	15	10	2	37	10	2	37	10	2	37
Allis shad	2	0	13	5	1	33	5	1	33	5	1	33
Sea lamprey	2	0	13	5	1	33	1	0	7	1	0	7
Salmon	0	0	0	0	0	0	0	0	0	0	0	0

	EAV equivalent weight (t)			mean SSB (t)	EAV weight as % of SSB			Mean landings (t)	EAV weight as % of landings		
Species	**Mean**	**Lower**	**Upper**		**Mean**	**Lower**	**Upper**		**Mean**	**Lower**	**Upper**
Sprat	56.2	22.0	143.7	220,757	**0.03**	**0.01**	**0.07**	151,322	0.04	0.01	0.09

	EAV equivalent weight (t)			**mean SSB (t)**	**EAV weight as % of SSB**			**Mean landings (t)**	**EAV weight as % of landings**		
Species	**Mean**	**Lower**	**Upper**		**Mean**	**Lower**	**Upper**		**Mean**	**Lower**	**Upper**
Herring	344.9	37.9	3,137.6	2,198,449	**0.02**	**0.00**	**0.14**	400,244	0.09	0.01	0.78
Whiting	104.5	25.6	425.9	151,881	**0.07**	**0.02**	**0.28**	17,570	0.59	0.15	2.42
Bass	109.0	29.7	400.9	14,897	**0.73**	**0.20**	**2.69**	3,051	3.57	0.97	13.14
Sand goby	0.1	0.0	0.6	205,882,353	**0.04**	**0.01**	**0.14**	NA	NA	NA	NA
Sole	2.4	1.0	6.1	43,770	**0.01**	**0.00**	**0.01**	12,800	0.02	0.01	0.05
Dab	0.6	0.1	4.1	NA	NA	NA	NA	6,135	**0.02**	**0.00**	**0.16**
Anchovy	1.5	0.2	9.4	NA	NA	NA	NA	1,625	**0.09**	**0.01**	**0.58**
Thin-lipped grey mullet	1.6	0.0	73.9	NA	NA	NA	NA	120	**1.35**	**0.03**	**61.61**
Flounder	0.5	0.2	1.3	NA	NA	NA	NA	2,309	**0.02**	**0.01**	**0.06**
Plaice	0.5	0.2	1.4	690,912	**0.00**	**0.00**	**0.00**	80,367	0.00	0.00	0.00
Smelt	0.3	0.1	0.9	105,733,825	**0.02**	**0.01**	**0.05**	8	3.56	1.23	10.36
Cod	9.9	2.5	39.3	103,025	**0.01**	**0.00**	**0.04**	34,701	0.03	0.01	0.11
Thornback ray	1.4	0.4	5.1	NA	NA	NA	NA	1,573	**0.09**	**0.03**	**0.33**
River lamprey	0.1	0.0	0.3	62	**0.18**	**0.06**	**0.53**	1	9.82	3.47	29.68
Eel	0.3	0.1	0.9	79	**0.39**	**0.16**	**1.11**	14	2.20	0.89	6.27
Twaite shad	1.1	0.2	7.4	7,519,986	**0.05**	**0.01**	**0.32**	1	84.60	13.50	557.82
Horse mackerel	0.6	0.1	4.3	NA	NA	NA	NA	20,798	**0.00**	**0.00**	**0.02**
Mackerel	0.2	0.1	0.3	3,888,854	**0.00**	**0.00**	**0.00**	1,026,828	0.00	0.00	0.00
Tope	0.3	0.1	0.5	NA	NA	NA	NA	498	**0.05**	**0.03**	**0.11**
Sea trout	0.0	0.0	0.1	NA	NA	NA	NA	39,795	**0.02**	**0.01**	**0.09**
Allis shad	0.0	0.0	0.0	27,397	**0.02**	**0.00**	**0.12**	0.2	1.79	0.30	12.50
Sea lamprey	0.0	0.0	0.0	NA	NA	NA	NA	NA	NA	NA	NA
Salmon	0.0	0.0	0.0	NA	NA	NA	NA	38,456	**0.00**	**0.00**	**0.00**

C.4 Predicted SZC impingement with the effect of LVSE intake heads and FRR systems fitted

	Annually raised SZB estimate			Annually raised SZC estimate			Intake head mortality		
Species	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**	**Mean**	**Lower**	**Upper**
Sprat	2,782,934	1,089,329	7,110,821	7,125,393	2,789,105	18,206,464	2,729,025	1,068,227	6,973,076
Herring	998,201	109,735	9,081,550	2,555,783	280,965	23,252,294	978,865	107,610	8,905,629
Whiting	728,597	178,790	2,969,271	1,865,492	457,773	7,602,486	714,484	175,327	2,911,752
Bass	224,719	61,132	826,468	575,367	156,523	2,116,078	220,366	59,948	810,458
Sand goby	149,045	40,410	549,860	381,612	103,464	1,407,855	146,157	39,627	539,208
Sole	97,665	39,070	244,218	250,059	100,033	625,293	95,773	38,313	239,487
Dab	58,163	8,659	390,758	148,921	22,171	1,000,493	57,037	8,491	383,189
Anchovy	28,849	4,627	180,746	73,865	11,847	462,780	28,290	4,537	177,245
Thin-lipped grey mullet	26,435	578	1,209,172	67,684	1,480	3,095,949	25,923	567	1,185,748
Flounder	14,912	6,298	35,319	38,180	16,125	90,431	14,623	6,176	34,635
Plaice	9,877	3,306	29,540	25,288	8,464	75,633	9,685	3,242	28,967
Smelt	9,320	3,216	27,101	23,863	8,233	69,389	9,139	3,153	26,576
Cod	6,579	1,678	26,056	16,845	4,297	66,715	6,451	1,646	25,552
Thornback ray	4,219	1,185	15,492	10,802	3,034	39,665	4,137	1,162	15,192
River lamprey	2,624	929	7,935	6,720	2,378	20,316	2,574	911	7,781
Eel	1,764	714	5,015	4,516	1,828	12,841	1,730	700	4,918
Twaite shad	1,407	224	9,275	3,601	575	23,747	1,379	220	9,095
Horse mackerel	1,592	312	11,890	4,077	800	30,442	1,561	306	11,659
Mackerel	245	180	352	628	460	900	241	176	345
Tope	25	12	51	64	31	132	24	12	50
Sea trout	4	1	15	10	2	37	4	1	14
Allis shad	2	0	13	5	1	33	2	0	13
Sea lamprey	2	0	13	5	1	33	2	0	13
Salmon	0	0	0	0	0	0	0	0	0

Species	Trash rack mortality			Drum screen mortality			Band screen mortality		
	Mean	Lower	Upper	Mean	Lower	Upper	Mean	Lower	Upper
Sprat	0	0	0	2,483,413	972,087	6,345,499	245,612	96,140	627,577
Herring	700,081	76,962	6,369,275	253,694	27,889	2,308,082	25,091	2,758	228,272
Whiting	0	0	0	328,991	80,731	1,340,745	64,304	15,779	262,058
Bass	52	14	191	101,446	27,597	373,095	19,828	5,394	72,924
Sand goby	0	0	0	27,399	7,428	101,080	2,710	735	9,997
Sole	0	0	0	17,954	7,182	44,894	1,776	710	4,440
Dab	23,886	3,556	160,473	6,214	925	41,750	615	92	4,129
Anchovy	0	0	0	25,744	4,129	161,293	2,546	408	15,952
Thin-lipped grey mullet	7	0	336	11,933	261	545,835	2,332	51	106,687
Flounder	459	194	1,086	2,655	1,121	6,289	263	111	622
Plaice	0	0	0	1,816	608	5,430	180	60	537
Smelt	0	0	0	8,317	2,870	24,184	823	284	2,392
Cod	40	10	160	3,267	834	12,940	577	147	2,285
Thornback ray	0	0	0	776	218	2,848	77	22	282
River lamprey	0	0	0	482	171	1,459	48	17	144
Eel	0	0	0	324	131	922	32	13	91
Twaite shad	1,218	194	8,030	147	23	969	15	2	96
Horse mackerel	0	0	0	1,421	279	10,610	141	28	1,049
Mackerel	0	0	0	219	160	314	22	16	31
Tope	0	0	0	5	2	9	0	0	1
Sea trout	4	1	14	0	0	0	0	0	0
Allis shad	2	0	13	0	0	0	0	0	0
Sea lamprey	0	0	0	0	0	2	0	0	0
Salmon	0	0	0	0	0	0	0	0	0

Species	Total FRR mortality			EAV equivalent numbers			EAV equivalent weight (t)		
	Mean	Lower	Upper	Mean	Lower	Upper	Mean	Lower	Upper
Sprat	2,729,025	1,068,227	6,973,076	2,050,190	802,510	5,238,549	21.53	8.43	55.02

Herring	978,865	107,610	8,905,629	700,103	76,964	6,369,473	132.08	14.52	1,201.70
Whiting	393,295	96,511	1,602,803	140,044	34,365	570,723	40.03	9.82	163.12
Bass	121,326	33,005	446,211	27,172	7,392	99,934	41.60	11.32	152.98
Sand goby	30,108	8,163	111,077	30,108	8,163	111,077	0.06	0.02	0.21
Sole	19,729	7,892	49,334	4,200	1,680	10,502	0.90	0.36	2.25
Dab	30,715	4,573	206,352	13,656	2,033	91,746	0.56	0.08	3.74
Anchovy	28,290	4,537	177,245	27,558	4,420	172,656	0.57	0.09	3.58
Thin-lipped grey mullet	14,273	312	652,858	1,190	26	54,420	0.62	0.01	28.30
Flounder	3,377	1,426	7,997	1,559	659	3,693	0.13	0.05	0.30
Plaice	1,995	668	5,967	689	231	2,061	0.17	0.06	0.51
Smelt	9,139	3,153	26,576	6,959	2,401	20,236	0.12	0.04	0.33
Cod	3,884	991	15,385	1,395	356	5,525	3.63	0.93	14.38
Thornback ray	852	239	3,130	164	46	603	0.52	0.15	1.93
River lamprey	530	188	1,603	530	188	1,603	0.04	0.01	0.13
Eel	356	144	1,013	356	144	1,013	0.12	0.05	0.33
Twaite shad	1,379	220	9,095	1,379	220	9,095	0.43	0.07	2.85
Horse mackerel	1,561	306	11,659	1,561	306	11,659	0.22	0.04	1.64
Mackerel	241	176	345	241	176	345	0.08	0.06	0.11
Tope	5	2	10	5	2	10	0.03	0.02	0.07
Sea trout	4	1	14	4	1	14	0.01	0.00	0.02
Allis shad	2	0	13	2	0	13	0.00	0.00	0.01
Sea lamprey	0	0	3	0	0	3	0.00	0.00	0.00
Salmon	0	0	0	0	0	0	0.00	0.00	0.00

Note: Total FRR mortality is the sum of the trash rack, drum screen and band screen mortalities, applied to the numbers impinged after the effect of the intake head has been considered.

	mean SSB (t)	EAV weight as % of SSB			Mean landings (t)	EAV weight as % of landings		
Species		**Mean**	**Lower**	**Upper**		**Mean**	**Lower**	**Upper**

Sprat	220,757	**0.01**	**0.00**	**0.02**	151,322	0.01	0.01	0.04
Herring	2,198,449	**0.01**	**0.00**	**0.05**	400,244	0.03	0.00	0.30
Whiting	151,881	**0.03**	**0.01**	**0.11**	17,570	0.23	0.06	0.93
Bass	14,897	**0.28**	**0.08**	**1.03**	3,051	1.36	0.37	5.01
Sand goby	205,882,353	**0.01**	**0.00**	**0.05**	NA	NA	NA	NA
Sole	43,770	**0.00**	**0.00**	**0.01**	12,800	0.01	0.00	0.02
Dab	NA	NA	NA	NA	6,135	**0.01**	**0.00**	**0.06**
Anchovy	NA	NA	NA	NA	1,625	**0.04**	**0.01**	**0.22**
Thin-lipped grey mullet	NA	NA	NA	NA	120	**0.52**	**0.01**	**23.60**
Flounder	NA	NA	NA	NA	2,309	**0.01**	**0.00**	**0.01**
Plaice	690,912	**0.00**	**0.00**	**0.00**	80,367	0.00	0.00	0.00
Smelt	105,733,825	**0.01**	**0.00**	**0.02**	8	1.36	0.47	3.97
Cod	103,025	**0.00**	**0.00**	**0.01**	34,701	0.01	0.00	0.04
Thornback ray	NA	NA	NA	NA	1,573	**0.03**	**0.01**	**0.12**
River lamprey	62	**0.07**	**0.02**	**0.20**	1	3.76	1.33	11.37
Eel	79	**0.15**	**0.06**	**0.42**	14	0.84	0.34	2.40
Twaite shad	7,519,986	**0.02**	**0.00**	**0.12**	1	32.40	5.17	213.64
Horse mackerel	NA	NA	NA	NA	20,798	**0.00**	**0.00**	**0.01**
Mackerel	3,888,854	**0.00**	**0.00**	**0.00**	1,026,828	0.00	0.00	0.00
Tope	NA	NA	NA	NA	498	**0.01**	**0.00**	**0.01**
Sea trout	NA	NA	NA	NA	39,795	**0.01**	**0.00**	**0.04**
Allis shad	27,397	**0.01**	**0.00**	**0.05**	0	0.68	0.11	4.79
Sea lamprey	NA	NA	NA	NA	NA	NA	NA	NA
Salmon	NA	NA	NA	NA	38,456	**0.00**	**0.00**	**0.00**

Appendix D Mean numbers of fish estimated impinged annually at SZB

Annually raised mean SZB estimates of impingement for 24 key species, with no mitigation and with the embedded FRR mitigation. Total losses have been converted to adult equivalent (EAV) numbers and weights (t) and calculated as a percentage of either the mean stock SSB (t) or mean international landings (t). Species where the impingement weight exceed 1 % of the relevant stock comparator are shaded in red. Note: numbers in red font are either estimates of the population numbers (e.g. sand goby) or reported catch numbers (salmon and sea trout).

D.1 Unmitigated impingement effects

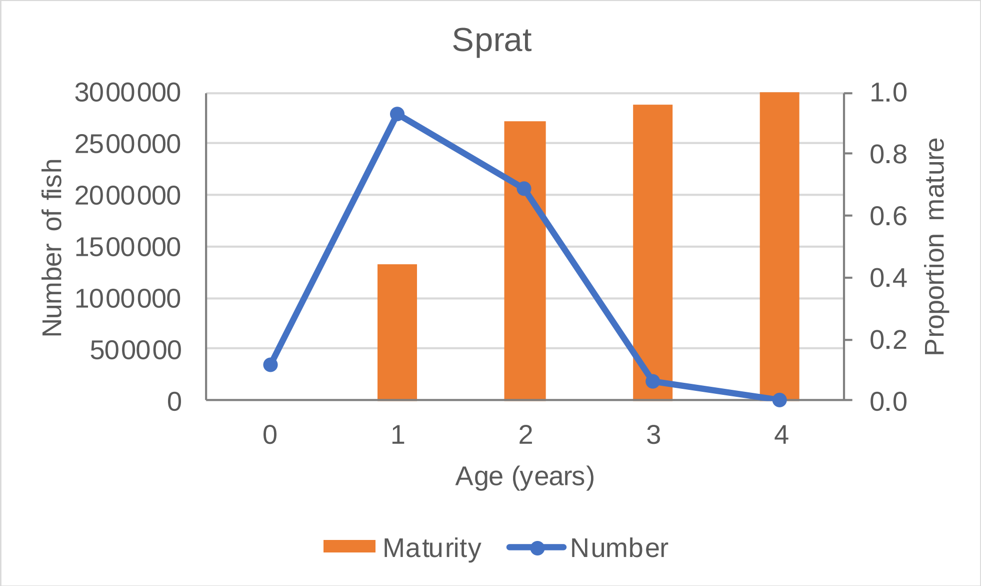
Species	Mean SZB estimate	EAV number	EAV weight (t)	Mean SSB	% of SSB	Mean landings (t)	% of landings
Sprat	2,782,934	2,090,690	21.96	220,757	**0.01**	151,322	0.01
Herring	998,201	713,932	134.69	2,198,449	**0.01**	400,244	0.03
Whiting	728,597	259,437	74.15	151,881	**0.05**	17,570	0.42
Bass	224,719	50,329	77.04	14,897	**0.52**	3,051	2.53
Sand goby	149,045	149,045	0.28	205,882,353	**0.07**	NA	NA
Sole	97,665	20,791	4.45	43,770	**0.01**	12,800	0.03
Dab	58,163	25,860	1.06	NA	NA	6,135	**0.02**
Anchovy	28,849	28,102	0.58	NA	NA	1,625	**0.04**
Thin-lipped grey mullet	26,435	2,204	1.15	NA	NA	120	**0.96**
Flounder	14,912	6,886	0.56	NA	NA	2,309	**0.02**
Plaice	9,877	3,411	0.84	690,912	**0.00**	80,367	0.00
Smelt	9,320	7,096	0.12	105,733,825	**0.01**	8	1.39
Cod	6,579	2,363	6.15	103,025	**0.01**	34,701	0.02
Thornback ray	4,219	813	2.60	NA	NA	1,573	**0.17**
River lamprey	2,624	2,624	0.21	62	**0.34**	1	18.61
Eel	1,764	1,764	0.58	79	**0.74**	14	4.18
Twaite shad	1,407	1,407	0.44	7,519,986	**0.02**	1	**33.04**
Horse mackerel	1,592	1,592	0.22	NA	NA	20,798	**0.00**
Mackerel	245	245	0.08	3,888,854	**0.00**	1,026,828	0.00
Tope	25	25	0.17	NA	NA	498	**0.03**
Sea trout	4	4	0.01	NA	NA	39,795	**0.01**
Allis shad	2	2	0.00	27,397	**0.01**	0	**0.70**
Sea lamprey	2	2	0.00	NA	NA	NA	NA
Salmon	0	0	0.00	NA	NA	38,456	**0.00**

D.2 Impingement effects with embedded FRR mitigation

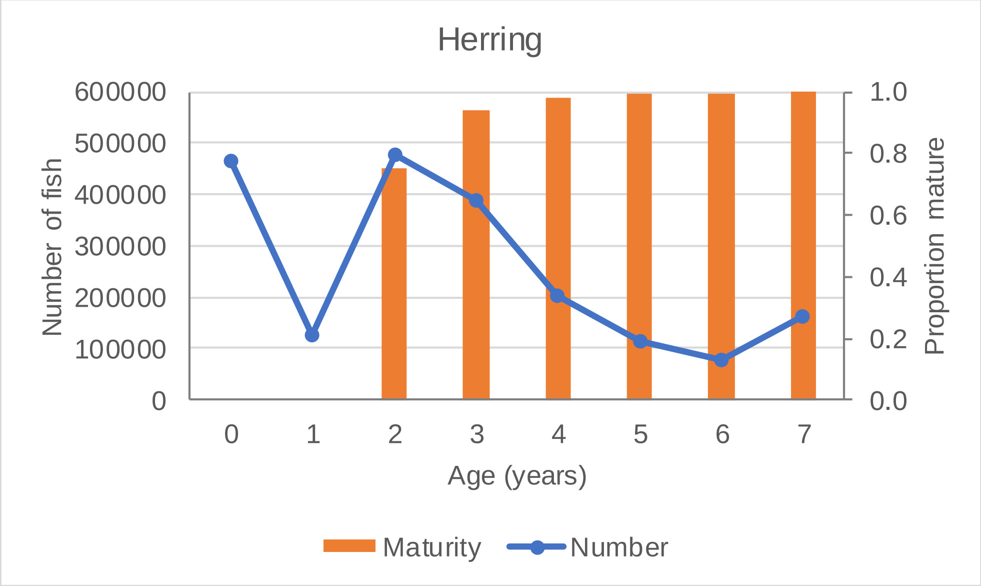
Species	Mean SZB estimate	FRR mortality	EAV number	EAV weight (t)	Mean SSB	% of SSB	Mean landings (t)	% of landings
Sprat	2,782,934	2,782,934	2,090,690	21.96	220,757	**0.01**	151,322	0.01
Herring	998,201	998,201	713,932	134.69	2,198,449	**0.01**	400,244	0.03
Whiting	728,597	364,299	129,719	37.08	151,881	**0.02**	17,570	0.21
Bass	224,719	112,359	25,164	38.52	14,897	**0.26**	3,051	1.26
Sand goby	149,045	29,809	29,809	0.06	205,882,353	**0.01**	NA	NA
Sole	97,665	19,533	4,158	0.89	43,770	**0.00**	12,800	0.01
Dab	58,163	11,633	5,172	0.21	NA	NA	6,135	**0.00**
Anchovy	28,849	28,849	28,102	0.58	NA	NA	1,625	**0.04**
Thin-lipped grey mullet	26,435	13,218	1,102	0.57	NA	NA	120	**0.48**
Flounder	14,912	2,982	1,377	0.11	NA	NA	2,309	**0.00**
Plaice	9,877	1,975	682	0.17	690,912	**0.00**	80,367	0.00
Smelt	9,320	9,320	7,096	0.12	105,733,825	**0.01**	8	1.39
Cod	6,579	3,289	1,181	3.07	103,025	**0.00**	34,701	0.01
Thornback ray	4,219	844	163	0.52	NA	NA	1,573	**0.03**
River lamprey	2,624	525	525	0.04	62	**0.07**	1	3.72
Eel	1,764	353	353	0.12	79	**0.15**	14	0.84
Twaite shad	1,407	1,407	1,407	0.44	7,519,986	**0.02**	1	**33.04**
Horse mackerel	1,592	1,592	1,592	0.22	NA	NA	20,798	**0.00**
Mackerel	245	245	245	0.08	3,888,854	**0.00**	1,026,828	0.00
Tope	25	5	5	0.03	NA	NA	498	**0.01**
Sea trout	4	2	2	0.00	NA	NA	39,795	**0.00**
Allis shad	2	2	2	0.00	27,397	**0.01**	0	**0.70**
Sea lamprey	2	0	0	0.00	NA	NA	NA	NA
Salmon	0	0	0	0.00	NA	NA	38,456	**0.00**

Appendix E Number at age and proportion maturity of commonly impinged fish species

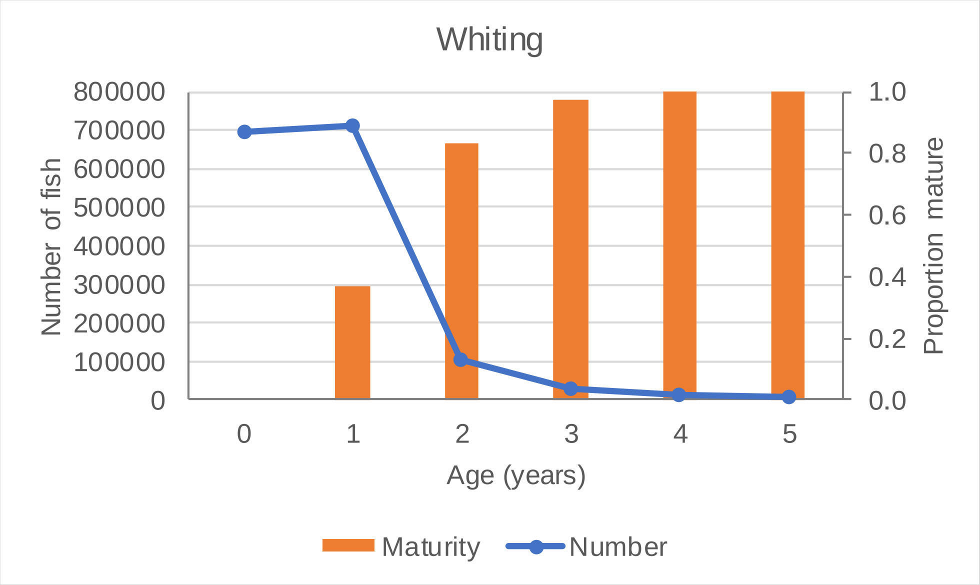
E.1 Sprat



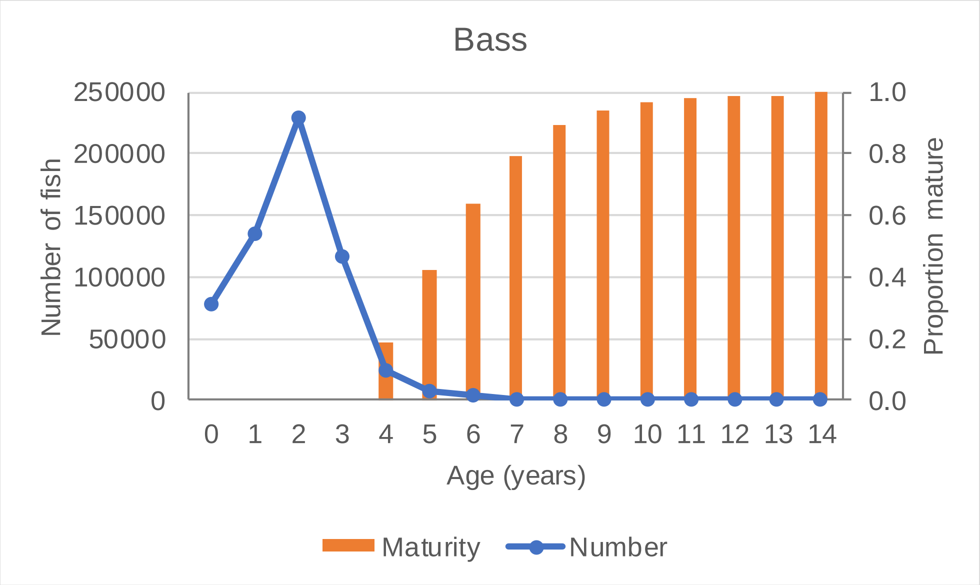
E.2 Herring



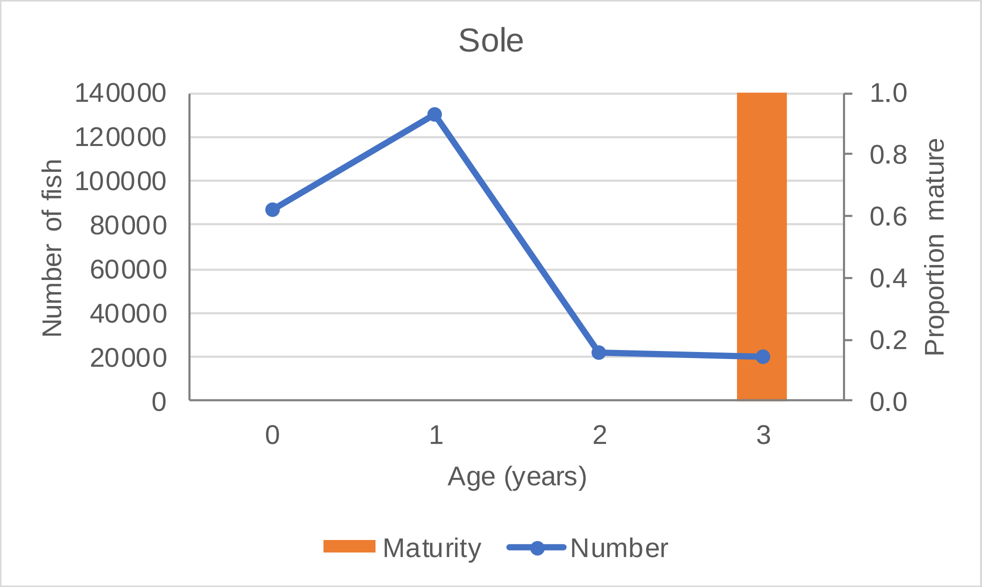
E.3 Whiting



E.4 Bass



E.5 Sole


Sole
Number of fish
140000
120000
100000
80000
60000
40000
20000
0
Proportion mature
1.0
0.8
0.6
0.4
0.2
0.0
0
1
2
3
Age (years)
Maturity
Number