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Worst case glass eel entrainment assessment for HPC

Worst case glass eel entrainment assessment for HPC

Brian Robinson

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Executive summary

Consultees on the HPC Water Discharge Activity (WDA) operational permit variation need to have evidence that HPC with no Acoustic Fish Deterrent (AFD) fitted will not cause adverse effects on the SAC/Ramsar fish assemblages nor on the specific fish species that are designated interest features in their own right. A quantitative effects assessment has previously been prepared in BEEMS[1] Technical Report TR456 that assessed the HPC effects on 20 representative fish species (including all of the designated fish qualifying features) as negligible.

After the WDA permit variation was submitted by NNB GenCo (HPC) Ltd, the Environment Agency has issued a series of draft technical briefs which collectively propose alternative assessment methodologies and provide different results than those provided in TR456. Some of these differences are material. One of the species that the Environment Agency has raised concerns over is European eel; in particular the Environment Agency has raised concerns over the effects of glass eel entrainment at HPC. In its draft technical brief TB004 the Environment Agency has predicted a mean of 1.38M glass eels being entrained per year in HPC based upon the application of a mean density calculated from the results of the BEEMS 2012 and 2013 glass eel surveys (BEEMS Technical Reports TRS211 and TR274). These glass eel surveys were undertaken under a joint programme funded by EDF Energy and the Environment Agency and consisted of three separate campaigns conducted over a period of 2 years during the peak migration period for glass eels in February to April. The surveys were undertaken over the full width of the estuary at Hinkley Point at up to three different depths and consisted of 323 fishing tows with gear optimised for sampling glass eels.

The Environment Agency has not yet presented its conclusions on the entrapment effects of HPC on the local eel population in its draft summary report TB020.

The Environment Agency conducted an Appropriate Assessment in 2012 as part of the determination of the WDA permit for HPC. That appropriate assessment concluded that HPC would not have an adverse effect on the eel population of the Severn Estuary and Bristol Channel as a result of entrainment. Eels are not deterred by AFD systems and so the removal of the HPC AFD would have no effect on eel entrainment (nor impingement) losses and so a new assessment of eel entrainment was not conducted in TR456.

In this paper (SPP107), the HPC glass eel entrainment has been recalculated and presented as the expected loss of equivalent silver eel biomass per annum to enable comparison with the estimated escapement biomass (the relevant eel stock value) in the Severn and South West River Basin Districts provided in TB018. A key part of this revised assessment is a reasonableness assessment of the TB004 method of calculating the number of eels entrained. This test calculates the annual recruitment of silver eels from the BEEMS glass eel density measurements across the full width of the Severn Estuary during the migration season. The resulting estimate of silver eel recruitment is found to be much higher than that expected during 'pristine' conditions before the stock collapsed in the late 1970s. Annual glass eel recruitment has reduced substantially since then and has only recently showed tentative signs of a recovery. Making the overly conservative assumption that annual silver eel recruitment is at the level that it was in pristine conditions, the assumptions used in TB004 lead to overestimates of silver eel recruitment by a factor of 58 if data from the February to March 2013 survey (when glass eel densities were at their highest) are used in the calculation; or 35.4 if averages from all the 2012 and 2013 survey data are used as in the Environment Agency's draft methodology in TB004. The reason that the silver eel recruitment estimates are too high is considered to be due to invalid initial assumptions about the spatial and temporal variability of eel density in the estuary.

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[1] The Centre for Environment, Fisheries and Aquaculture science (Cefas) has been contracted by NNB GenCo (HPC) Ltd to provide the marine evidence base to meet regulatory requirements for the HPC Project via a comprehensive set of studies known collectively as the BEEMS programme for HPC.

Estimates of silver eel entrainment for HPC and HPB are calculated as silver eel losses in tonnes per annum or as a percentage of escapement biomass after scaling the data by the factors determined in the reasonableness test. For completeness the expected total eel mortality (entrainment plus impingement) after HPC becomes operational is also calculated in tonnes and as a percentage of the escapement biomass.

The effects of HPC are assessed assuming the following embedded impingement mitigations:

- Low velocity side entry (LVSE) intake heads;
- A Fish Recovery and Return (FRR) system;

and the additional mitigation of the closure of Hinkley Point B (HPB) before HPC becomes operational.

The summarised results are presented in Table 1 and Table 2 based upon using the survey data with peak densities only (2013 February-March) or all the survey data respectively.

Table 1 Calculated eel losses as a percentage of escapement biomass in the relevant assessment years using data from February-March 2013 only

Station	Entrainment as a % of escapement biomass	Impingement as a % of escapement biomass
HPC	0.036%	0.027%
HPB	0.016%	0.047%
Net effect after HPC operational (and HPB ceased operation)	+0.020%	-0.020%

Table 2 Calculated eel losses as a percentage of escapement biomass in the relevant assessment years using all survey data

Station	Entrainment as a % of escapement biomass	Impingement as a % of escapement biomass
HPC	0.028%	0.027%
HPB	0.017%	0.047%
Net effect after HPC operational (and HPB ceased operation)	+0.011%	-0.020%

Conclusions

Based on the results of this assessment the following conclusions about eel mortality after HPC becomes operational have been derived:

a. The predicted impingement and entrainment losses after HPC becomes operational are negligible as a percentage of escapement biomass based upon precautionary assessments.

b. There will be no net losses of eels when HPC becomes operational. Due to the precautionary nature of the assessments, it is considered likely that there will be a net reduction in losses of eel as a percentage of escapement biomass after HPC becomes operational.

c. There will be no adverse effect on eels in the Severn and South West River Basin Districts from the operation of HPC.

1 Background

Predictions of the effects of HPC cooling water abstraction on fish stocks were provided in BEEMS Technical Report TR456 Edition 2 v10 which was produced to provide part of the evidence base for the proposed Water Discharge Activity (WDA) permit variation for HPC to remove the Acoustic Fish Deterrent system. For eel, TR456 only provided an impingement assessment as the entrainment assessment completed at the time of the DCO had previously concluded negligible effect. This conclusion was reached based after calculation of the predicted additional effect of HPC on the natural mortality of glass eel. The assessment was highly precautionary and was based upon the results of the 2012 BEEMS glass eel survey (TRS211), a joint programme funded by EDF Energy and the Environment Agency. The results of the 2012 survey were shared with the EA so that they could use them during the preparation of their Appropriate Assessment of HPC (Environment Agency 2012). The Appropriate Assessment concluded:

> *"We would thus agree that such increases are not significant, and as these calculations are very conservative and are based on worst case scenario. We can therefore conclude that the abstraction at HPC alone will not have an adverse effect on the eel population of the Severn Estuary and Bristol channel as a result of entrainment"*

In the light of the previously presented evidence, the Environment Agency's conclusion in 2012 and the fact that the removal of the Acoustic Fish deterrent would have no effect on the abstraction of eel (impingement or entrainment), the eel entrainment calculation was not revisited in TR456.

TR456 has been discussed at length with consultees and has been revised in successive releases in response to consultee comments. After submission of the WDA permit variation for HPC, the Environment Agency has issued a series of draft technical briefs which collectively propose alternative assessment methodologies and provide different results than those provided in TR456; some of which are material. Technical briefs TB004 and TB018 contained calculations on the predicted entrainment effects of HPC on glass eels and information on the relevant eel stock sizes. The draft results summary report (TB020) contains no conclusions for eel. TB004 states:

> *"SPP073/S (BEEMS, 2012) discusses entrainment of glass eels but does not quantify entrainment numbers and is not in a format that can be integrated into the current assessment framework."*
> (Note: the reference should have been to SPP063/S not SPP073/S)

TB004 is correct in that SPP063/S does not provide predictions of absolute numbers of entrained eel and instead provides the results of a quantitative assessment of the changes in glass eel mortality with and without HPC which demonstrated the negligible effect of HPC entrainment.

TB004 Table 5 provides a prediction of a mean of 1.379M glass eels being entrained per year based upon a mean density at HPC calculated from the results of the BEEMS 2012 and 2013 glass eel surveys (BEEMS Technical Reports TRS211 and TR274). The TB004 draft entrainment calculation is understood but the provenance and relevance of the other parameters in that table are unclear (entrainment mortality and EAV) as they could not be located in the references provided in TB004. (The mean densities in Table 3 of TB0034 are small overestimates of those calculated from the raw data but the difference is not material and result in a slightly lower calculated HPC entrainment of 1.333M glass eels). In this paper, the HPC eel entrainment is recalculated and presented as the expected loss of equivalent silver eels per annum to enable comparison with local stock estimates. A key part of this revised assessment is a reasonableness assessment of the TB004 method of calculating the number of eels entrained to determine whether the results are credible

2 Revised glass eel entrainment assessment

The following assumptions have been used for this report which are the same as those used in TB004:

i. glass eel density estimates are from the BEEMS surveys (TRS211, TR274);
ii. glass eel density is constant with depth;
iii. glass eels are only entrained at HPC in significant numbers on the flood tide when they spend 12h in the water column. On the ebb glass eels are considered to be on or in the seabed;
iv. glass eel density is constant for the 90-day migration period

The differences with TB004 assumptions are:

a. Entrainment Mortality

In SPP063/S the evidence for glass eel entrainment mortality indicated a range of 1.8% to 15%. In this report, we have used a more precautionary and more recent value obtained from a series of experiments conducted in the BEEMS entrainment mimic unit (EMU) which was designed to simulate the full range of conditions that entrained organisms would experience inside of HPC (BEEMS Technical Report TR273). These experiments simulated the exposure of glass eels to mechanical, thermal, pressure and chemical impacts from abstraction to discharge. The simulations included filtration through a 5mm mesh, the time of exposure in the HPC cooling water system, the profile of temperature (delta T +11.6°C) and pressure (peak change 4bar) and also the effects of chlorination at a TRO level of 0.2mg/l (HPC will not apply chlorination and the simulation was therefore precautionary). The simulations did not include the impact of the periodic discharge of residual levels of waste hydrazine via the cooling water system because the predicted levels and durations would not have any adverse effect on glass eels (BEEMS Technical Report TR318).

Based upon the EMU experiments, the predicted entrainment mortality for glass eels in HPC is 20% which is considered precautionary as the EMU dimensions (in particular, the radius of bends in the pipework) were too small for glass eel experiments and created greater mechanical stress than will be experienced in HPC.

The value used for entrainment mortality makes little difference to the calculated net entrainment losses after HPC becomes operational (Section 2.4) and so it is not considered further in this paper.

b. Glass eel density assumptions

TB004 calculates a mean density from the 3 BEEMS glass eel surveys in 2012 (TRS211) and 2013 (TR274) calculated by taking a mean of the means from each survey. There is nothing wrong with such a calculation, but the survey results show clearly that the glass eel density in the estuary changes from year to year and also within the migration period in a year and by averaging the data the glass eel dynamics are obscured, and some insight may be lost. For simplicity, in this report, the revised entrainment results have been presented using eel densities from the peak density period in February to March 2013 (TR274). In the Appendix, results are also presented using the TB004 method of averaging all of the survey data; the HPC entrainment predictions are not materially different either way. The revised entrainment result is shown in Table 3.

Table 3 Revised HPC entrainment based upon February to March 2013 survey results and entrainment mortality calculated from EMU experiments

Glass eel density	HPC cumecs	Eels/s entrained	Number entrained in 90 days (flood tide)	Entrainment mortality	Glass eel mortality	Silver eel equivalents t
5.56E-03	131.86	0.733	2,850,455	20%	570,091	11.17

Note: Where 1kg glass eels = 59.4kg silver eels (Defra, 2018)

The predicted annual loss is 11.2 t per annum. The next section of this report determines whether this number is credible.

2.1 Reasonableness test on the eel density assumptions used to derive glass eel entrainment numbers in TB004.

A simple reasonableness test is to calculate what the density assumptions mean in terms of silver eel recruitment to the population from migration in the entire estuary.

In the BEEMS glass eel surveys, glass eels were caught all the way across the Severn. A density profile has been constructed by splitting the 23km estuary cross section from HPC to Penarth into 5 sections using the location descriptors from TRS211/TR274 and pooling the results in each section as shown in Table 4. The five sections are:

- English Parallel and HPB. These data were combined because the distance offshore was approximately the same for all survey locations. (section width 2km, i.e. ±1km)
- HPC (section width 2km)
- Parrett (section width 3km)
- Pooled values from the south to north and north to south transects omitting locations that overlapped with Penarth, Parrett and HPC locations. These transects used V profile sampling whereas the other locations consisted of horizontal tows at a fixed depth (TR274). The V profile results are likely to be lower than those that would have been measured with the horizontal tows because with a V tow there is less time fishing at the surface where eel densities were the greatest. (section width 12km)
- Penarth (section width 4km). The Penarth density values are likely to be underestimates for the 4km section because surveys could not be conducted any closer to the coast. Surveys further to the east showed that densities were higher closer to shore, but these have not been included because they were off the selected HPC to welsh coast transect.

For each section, the mean depth was calculated from the measured bathymetry in the Severn (TR456). The flow of eels through each section was then calculated using the mean current speed at a height of 2.5m off the seabed of 0.45m/s from the validated GETM Hinkley Point model over a 30-day cycle. (Values were extracted for the location of the HPB and the HPC intakes, but the values were the same).

The mean number of eels per section per second = section width * depth * current speed * density in section

Mean number of glass eels in 90 days= eels/second * 3600 *12 * 90 (flood tides only)

The silver eel equivalent biomass was calculated from:

Glass eel weight = 0.33g and 1kg glass eel = 59.4kg silver eels (Defra 2018).

Table 4 Calculated Silver eel recruitment biomass in 5 sections across the Severn Estuary using February-March 2013 survey data (TR274)

Section	Glass eel density x 10^{-3}	Section width m		Mean depth m	Glass eels/s passing through section	Glass eels in 90 days	Silver eel equivalent t
English parallel & HPB	7.93	2000	15860	7.3	52.1	202,565,189	3,971
HPC	5.56	2000	11120	11.9	59.7	232,104,735	4,550
Parrett	3.15	3000	9450	15.2	64.6	251,312,544	4,926
Transects	1.8	12000	21600	20.2	196.3	763,385,472	14,964
Penarth	6.14	4000	24560	15.0	165.8	644,552,640	12,635
Totals		Mean density x 10^{-3}	**3.591**		538.6	2,093,920,580	**41,045**

Using the measured glass eel densities and the assumptions of constant density with depth and over the 90-day migration period used previously, the calculated silver eel recruitment per year is 41,045 t. This is not credible because the pristine biomass for the Severn (i.e. before the crash in the North Atlantic stock) is 900 t with an estimated best escapement value of 708 t (ICES 2018, Defra 2018). The maximum theoretical annual recruitment could be 708t (i.e. to replace the annual pristine escapement) but, at the current stock levels, the annual recruitment is much smaller than in pristine conditions. The current escapement is estimated at 81t which would imply that the annual recruitment is significantly less than 708t.

Assuming a maximum recruitment of 708t on a precautionary basis, the silver eel biomass is over estimated in Table 4 by a factor of at least 58 (41,045/708).

2.1.1 Why are the silver eel recruitment estimates too high?

There are three likely reasons why the recruitment estimates are too high:

i. Glass eel density is not constant with time and so the assumption of constant density for 90 days is not valid. For example, the BEEMS surveys in 2013 showed a reduction between the periods 19 February to 4 March and 6 April to 11 April of 80% in April at the HPC location and 60% at the HPB location. The April survey only covered the first third of April and densities could well have fallen even lower in the remainder of the month (TR274).

ii. Eel density is not constant with depth with highest densities being recorded in the top 0-1.4m depth for all locations in the BEEMS surveys. The BEEMS surveys showed a measured overall reduction between densities at 0m and 7m of 30%, 55% and 71% in the 3 surveys (TR274).

iii. Measurements of eel behaviour means that they are unlikely to spend the theoretical maximum of 12 hours per day in the water column on the flood used in calculations for Table 3 and Table 4. In the Gironde basin in France the measured transport efficiency of glass eels using selective tidal stream transport to migrate up estuary was 15% to 19% of the theoretical maximum. (Beaulaton and Castelnaud, 2005).

Glass eels migrating up estuary are considered to ascend off the estuary bed into the water column after the onset of the flood tide and rise to near the sea surface, particularly at night (Harrison *et al* 2014). The BEEMS surveys only measured glass eel density to a maximum depth of 7 to 8.4m. Based upon the trend from the BEEMS surveys it is considered highly likely that glass eel density is lower at the depth of the HPC intakes than higher in the water column (the intake surfaces will be at 8.5-10.5m depth at mid-tide and up to 6m lower at maximum water levels at the end of the flood). However, it was necessary to assume eel presence at this depth otherwise the calculated eel entrainment would be zero at HPC. (The counter argument that HPC could entrain glass eels on the ebb when they are close to the sea bed to make use of the lower velocities that would prevent them from being swept downstream is unlikely because to benefit from such low velocities they would have to be much closer to the bed than the HPC intake openings that start at 1.5m off the bed)

2.2 Recalculated HPC entrainment estimate corrected for fish density

The calculated HPC entrainment estimate in Table 3 is 11.2t per annum. After applying the minimum density correction factor of 58, the revised silver eel mortality is 0.19 t.

However, this calculation makes no allowance for the expected benefits from the Low Velocity Side Entry (LVSE) intake heads planned for HPC (BEEMS Scientific Position Paper SPP105).

These highly engineered intake structures are designed to minimise fish impingement by:

a. 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. they reduce the cross-sectional intercept area of the intake presented to the prevailing tidal directions by mounting the head orthogonal to the tidal flow;
b. reducing intake velocities into the head to a target velocity of 0.3 m s^{-1} over as much of the length of the intake surface as practical during all tidal states in order to maximise the possibility of most fish avoiding abstraction; and
c. reducing vertical velocities which fish are ill equipped to resist by means of velocity caps on the intakes.

The intercept area of the HPC intakes is calculated in SPP105 at 31m^2 or 46.5m^2 assuming the correction factor of 1.5 for the difference between modelled and measured ADCP current velocities at Hinkley Point (SPP105). However, this calculation takes into account abstraction at slack water when glass eels are unlikely to migrating. Assuming that glass eels migrate at current speeds above 0.1 m s^{-1}, the calculated intercept area of the HPC intakes (i.e. excluding abstraction at below 0.1 m s^{-1}) is approximately 19.3m^2 or 28.9m^2 with the correction factor of 1.5 for the difference between modelled and measured ADCP current velocities at Hinkley Point.

For this paper a more precautionary intercept area is calculated. Laboratory experiments in flume tanks have determined that glass eels can sustain swimming speeds of 0.15 m s^{-1} for at least 1 hour (Experimental results summarised in Langdon and Collins 2000). The Environment Agency recommends reducing intake velocities into the head to a target velocity of 0.3 m s^{-1} over as much of the length of the intake surface as practical during all tidal states in order to maximise the possibility of most fish avoiding abstraction. In this paper, a precautionary estimate of 0.05m s^{-1} has been assumed for the sustained swimming speed of glass eel. The distance from the HPC intake surfaces when the inwards velocity falls to 0.05m s^{-1} is 3m (SPP105). The intercept area of each head is therefore given by 3m * 2m height * 2 surfaces = 12m^2 or 48m^2 for 4 intakes. This figure is more precautionary than that calculated from the analyses in SPP105 due to taking account of the limited sustained swimming speed of glass eels.

Considering the calculated eel migration in the HPC section of the Severn estuary in Table 4:

Percentage HPC interception = height of intake surface/water depth *head intercept width/width of section

= 2/11.9 * 24/2000 =0.201%.

The predicted number of entrained glass eels and the resulting entrainment losses of silver eel in tonnes are shown in Table 5 at 1.83t or 0.032t after correction by the density factor of 58 derived in section 2.1 above.

Table 5 Revised glass eel entrainment after LVSE performance included and silver eel equivalent losses

Glass eels in 90 days in Section HPC	Percentage entrained by HPC	Number entrained	Entrainment mortality @20%	Silver eel equivalent without reasonableness correction t	Corrected silver eel mortality t (correction factor of 58 applied)
232,104,735	0.201%	466,933	93,387	1.83	0.032

In TR456, the calculated HPC eel impingement losses were calculated as 0.058 t (after a slight increase due to the revised LVSE performance factor in SPP105) and the HPB impingement losses were 0.1t.

2.3 HPB predicted glass eel entrainment

The design of the HPB intake head makes it difficult to predict the abstraction of glass eels. The intake has two surfaces; a horizontal surface which is omnidirectional and a vertical surface that faces approximately into the ebb tidal direction (SPP105). In principle, on the flood tide glass eel would only be abstracted via the horizontal surface. On a precautionary basis, and in line with the assumption in SPP105, it has been assumed that glass eels within a vertical distance of 1.5m from the horizontal intake surface will be abstracted and that this surface presents a projected width of 9.75m to the flood tide (SPP105). This is considered likely to be an underestimate of the HPB intake intercept area.

Considering the calculated eel migration in the HPB section of the Severn estuary in Table 4:

Percentage HPB interception = height of intake surface/water depth * head intercept width/width of section

= 1.5/7.3 * 9.75/2000 =0.10%.

The predicted number of entrained glass eels at HPB and the equivalent losses of silver eel due to entrainment in tonnes are 0.795t or 0.014t after correction by the factor of 58 derived in section 2.1 above; Table 6

Table 6 HPB Glass eel entrainment and silver eel equivalent losses

Glass eels in 90 days in Section HPB	Percentage entrained by HPB	Number entrained	Entrainment mortality @20%	Silver eel equivalent t	Corrected silver eel mortality t
202,565,189	0.100%	202,912	40,582	0.795	0.014

2.4 Summary of effects on European eel

The total silver eel mortalities at HPB and HPC are presented in Table 7. The impingement losses are based upon measurements made in 2009 and the entrainment losses are based upon measurement made in 2013.

Table 7 HPC and HPB predicted silver eel entrainmnet and impingement losses (tonnes per annum)

Station	Entrainment t	Impingement t	Total loss t
HPC	0.032	0.058	0.090
HPB	0.014	0.100	0.114

These data are expressed as a percentage of the estimated silver eel escapement biomass from TB018 of 87.178 t in 2014-2016 and 213.709 t in 2008-2010 in Table 8.

Table 8 Predicted impingement and entrainment as a percentage of escapement biomass in the relevant assessment years

Station	Entrainment as a % of the 2014-2016 escapement biomass	Impingement % of the 2008-2010 escapement biomass
HPC	0.036%	0.027%
HPB	0.016%	0.047%
Net effect after HPC operational (and HPB ceased operation)	+0.020%	-0.020%

After HPC is operational, HPB will no longer be operational and the net effects shown in Table 8 are for a slight increase in entrainment losses with a corresponding slight decrease in impingement losses i.e. no net effect on eel. As discussed in section 2.1 this is a highly precautionary assessment and, in reality, eel entrainment is considered likely to be smaller than that shown in Table 8. As discussed in section 3, after considering the precautionary nature of the assessments it is considered that eel losses as a percentage of escapement biomass will be lower when HPC is operational. Eels are not deterred by AFD systems and so the removal of the HPC AFD would have no effect on eel entrainment (nor impingement) losses.

Changes to the assumed entrainment mortality inside the power stations affect both the HPB and HPC entrainment estimates and so the value of the factor does not materially change the conclusions drawn on the net effect of HPC at the predicted levels of entrainment in HPB and HPC.

3 Discussion

Consultees on the HPC WDA permit variation need to have evidence that HPC with no Acoustic Fish Deterrent fitted will not cause adverse effects on the SAC/Ramsar fish assemblage nor on the specific fish species that are qualifying features in their own right. A quantitative effects assessment has previously been prepared in BEEMS Technical Report TR456 that assessed the HPC effects on 20 representative fish species (including all of the designated fish interest features) as negligible.

After the WDA permit variation was submitted by NNB GenCo (HPC) Ltd, the Environment Agency has issued a series of technical briefs which collectively propose alternative assessment methodologies and provide different results than those provided in TR456. One of the species that the Environment Agency has raised concerns over is European eel; in particular, in discussion, the Environment Agency has raised concerns over the effects of glass eel entrainment at HPC. In their draft technical brief TB004, the Environment Agency has provided a predicted mean of 1.38M glass eels being entrained per year in HPC based upon the application of a mean density calculated from the results of the BEEMS 2012 and 2013 glass eel surveys (BEEMS Technical Reports TRS211 and TR274) but has not yet presented any conclusions on the effect on the eel population in the draft summary report TB020.

The Environment Agency conducted an Appropriate Assessment in 2012 as part of the determination of the WDA permit for HPC. That appropriate assessment concluded that HPC would not have an adverse effect on the eel population of the Severn Estuary and Bristol Channel as a result of entrainment. The removal of the HPC AFD would have no effect on eel entrainment (nor impingement) losses and so no new assessment of eel entrainment was conducted for TR456.

In this paper (SPP107) the HPC glass eel entrainment has been recalculated and presented as the expected loss of equivalent silver eel biomass per annum to enable comparison with the estimated escapement biomass (the relevant eel stock value) in the Severn and South West River Basin Districts provided in TB018. A key part of this revised assessment is a reasonableness assessment of the TB004 method of calculating the number of eels entrained. This test calculates the annual recruitment of silver eels from the BEEMS glass eel density measurements across the full width of the Severn Estuary during the migration season of February to April. The resulting estimate of silver eel recruitment is found to be much higher than that expected during 'pristine' conditions before the stock collapse in the late 1970s. Annual glass eel recruitment has reduced substantially since then and has only recently showed tentative signs of a recovery. Making the overly conservative assumption that annual silver eel recruitment is at the level that it was in pristine conditions, the assumptions used in TB004 lead to overestimates of silver eel recruitment by a factor of 58 if data from the February to March 2013 survey when glass eel densities were at their highest are used in the calculation, or 35.4 (see Appendix) if averages from all the 2012 and 2013 survey data are used, as in TB004. The reason that the silver eel recruitment estimates are too high is considered to be due to invalid initial assumptions about the spatial and temporal variability of eel density in the estuary (namely that eels are uniformly distributed through the water column, their density does not vary annually or within season and make 100% use of the flood tide to migrate).

Estimates of glass eel entrainment for HPC and HPB are recalculated as silver eel losses in tonnes per annum (Table 7) or as a percentage of escapement biomass (Table 8) after scaling the data by the factors determined in the reasonableness test. For completeness the expected total eel mortality after HPC becomes operational is also presented in tonnes and as a percentage of the escapement biomass in the two tables.

The effects of HPC are assessed assuming the following embedded impingement mitigations:

- Low velocity side entry (LVSE) intake heads;
- A Fish Recovery and Return (FRR) system;

and the additional mitigation of the closure of Hinkley Point B (HPB) before HPC becomes operational.

BEEMS Scientific Position Paper SPP106 has already demonstrated that once HPC becomes operational that the eel impingement losses from HPC are predicted to be lower than they are now with HPB operational. This paper (SPP107) estimates that the predicted entrainment mortality will be slightly higher than it is now (0.036% of escapement biomass for HPC versus 0.016% of escapement biomass for HPB based upon the peak glass eel densities measured in the 2013 February to March survey with a net increase in silver eel entrainment losses of 0.02% of escapement biomass). In the Appendix the HPB and HPC entrainment losses have been recalculated using all of the BEEMS survey data as in TB004. These results show a slightly lower net entrainment loss of 0.011% of escapement biomass (0.028% of escapement biomass for HPC versus 0.017% of escapement biomass for HPB).

The following observations can be made about the eel mortality predictions in Table 7 and Table 8:

1. The calculated losses as a percentage of eel escapement are negligible in all cases;

2. The calculated entrainment losses have been overestimated because they are based upon an assumed current annual silver eel recruitment of 708t (i.e. the pristine escapement biomass). The current escapement biomass is estimated to be 87t and glass eel surveys indices show significantly reduced annual recruitment compared to pre-1980 (ICES 2018). The annual silver eel recruitment is therefore likely to be much less than 708t and the entrainment estimates in this paper are, therefore, considered to significantly overestimated;

3. The calculated impingement estimates are based upon an assumption that all of the eels impinged at Hinkley Point were silver eels (TR456). In fact, many would have been yellow eels and therefore the natural mortality of these eels before they become silver eels has not been accounted for. Conservatively impingement may have been over estimated by up to a factor of 2 (assuming 5 years natural mortality before the yellow eels become silver eels).

4. Considering the precautionary nature of the entrainment and impingement predictions described above, it is considered likely that there will be a reduction of eel losses as a percentage of escapement biomass when HPC becomes operational.

4 Conclusions

Based on the results of this assessment the following conclusions about eel mortality after HPC becomes operational have been derived:

a. The predicted impingement and entrainment losses after HPC becomes operational are negligible as a percentage of escapement biomass based upon precautionary assessments.

b. There will be no net losses of eels when HPC becomes operational. Due to the precautionary nature of the assessments, it is considered likely that there will be a reduction in net losses of eel as a percentage of escapement biomass after HPC becomes operational.

c. There will be no adverse effect on eels in the Severn and South West River Basin Districts from the operation of HPC.

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5 References

Beaulaton, L. & Castelnaud, G. (2005). The efficiency of selective tidal stream transport in glass eel entering the Gironde (France). Pêche Piscic. 5. 378-379. 10.1051/kmae:2005001.

BEEMS Technical Report TRS211.Glass eel distribution in the inner Bristol Channel / lower Severn Estuary. Cefas, Lowestoft.

BEEMS Scientific Position Paper SPP063/S Ed 2. Entrainment impact on organisms at Hinkley Point – supplementary note.Cefas, Lowestoft.

BEEMS Scientific Position Paper SPP105. Predicted performance of the HPC LVSE intake heads compared with the HPB intake. Cefas, Lowestoft.

BEEMS Scientific Position Paper SPP106. Assessment of local effects of HPC on the Hinkley Point fish assemblage. Cefas, Lowestoft.

BEEMS Technical Report TR273. Entrainment Mimic Unit (EMU) Experimental Programme Report: European glass eel (*Anguilla anguilla*), June 2013.Cefas, Lowestoft.

BEEMS Technical Report TR274. Dynamics of glass eels in the Bristol Channel 2012-2013. Cefas, Lowestoft.

BEEMS Technical Report TR318. Predictions of entrainment by Sizewell C in relation to adjacent fish and invertebrate populations. Cefas, Lowestoft.

BEEMS Technical Report TR456 Ed 2, v10. Revised Predictions of Impingement Effects at Hinkley Point C – 2018. Cefas, Lowestoft.

Defra, 2018. Report to the European Commission in line with Article 9 of the Eel Regulation 1100/2007 Implementation of UK Eel Management Plans - June 2018.

Environment Agency 2012. Hinkley Point C Appropriate Assessment for related Environment Agency permissions. Environment Agency

Harrison, A.J. ,Walker, A.M ., Pinder, A.C., Briand, C., Aprahamian. M. W. 2014. A review of glass eel migratory behaviour, sampling techniques and abundance estimates in estuaries implications for assessing recruitment, local production and exploitation. Rev. Fish Biol. Fisheries V24, Issue 1, pp 967-983

ICES 2018. Report of the Joint EIFAAC/ICES/GFCM Working Group on Eels (WGEEL), 5–12 September 2018, Gdańsk, Poland. ICES CM 2018/ACOM:15. 152 pp.

Langdon, S.A. & Collins, A.L. (2000) Quantification of the maximal swimming performance of Australasian glass eels, Anguilla australis and Anguilla reinhardtii, using a hydraulic flume swimming chamber, New Zealand Journal of Marine and Freshwater Research,34:4, 629-636.

TB004 Accounting for entrainment losses and difference in drum screen size. Environment Agency Technical Brief draft 02. 2019

TB018 Review of European (silver) Eel biomass escapement biomass for the Severn Estuary. Environment Agency Technical Brief draft 03, 2020

TB020 Summary Technical Brief: Summary of Quantitative Impact Assessment Results. Environment Agency Technical Brief draft 03, 2020

6 Appendix

In this section the calculations provided previously in this paper are repeated using mean of means from the survey data in February-March 2012, February-March 2013 and April 2013. There are no other changes to the calculations.

Table 9 Calculated Silver eel recruitment biomass in 5 sections across the Severn Estuary using all 3 survey periods in 2012 & 2013 (TRS211 and TR274)

Section	Glass eel density 10^{-3}	Section width m		Mean depth m	Glass eels/s passing through section	Glass eels in 90 days	Silver eel equivalent t
English parallel & HPB	5.25	2000	10500	7.3	34.5	134,106,840	2,629
HPC	2.6	2000	5200	11.9	27.9	108,538,186	2,128
Parrett	1.88	3000	5640	15.2	38.6	149,989,709	2,940
Transects	1.26	12000	15120	20.2	137.4	534,369,830	10,475
Penarth	3.35	4000	13400	15.0	90.5	351,669,600	6,893
Totals		Mean density x 10^{-3}	**2.168**		328.9	1,278,674,165	**25,065**

Assuming a maximum recruitment of 708t on a precautionary basis, the silver eel biomass is over estimated in Table 4 by a factor of at least 35.4 (25,065/708).

Table 10 Revised glass eel entrainment after LVSE performance included and silver eel equivalent losses (based upon 2012 & 2013 survey data)

Glass eels in 90 days in Section HPC	Percentage entrained by HPC	Number entrained	Entrainment mortality @20%	Silver eel equivalent t	Corrected silver eel mortality t (correction factor of 35.4 applied)
108,538,186	0.201%	218,350	43,670	0.86	0.024

Table 11 HPB Glass eel entrainment and silver eel equivalent losses (based upon 2012 & 2013 survey data)

Glass eels in 90 days in Section HPB	Percentage entrained by HPB	Number entrained	Entrainment mortality @20%	Silver eel equivalent t	Corrected silver eel mortality t
134,106,840	0.100%	134,336	26,867	0.527	0.015

Table 12 HPC and HPB predicted silver eel entrainmnet and impingement losses (tonnes per annum) (Based upon 2012 & 2013 survey data)

Station	Entrainment t	Impingement t	Total loss t
HPC	0.024	0.058	0.082
HPB	0.015	0.100	0.115

Table 13 Predicted impingement and entrainment as a percentage of escapement biomass in the relevant assessment years (Based upon using the 2012 & 2013 BEEMS glass eel survey data)

Station	Entrainment as a % of the 2014-2016 escapement biomass	Impingement % of the 2008-2010 escapement biomass
HPC	0.028%	0.027%
HPB	0.017%	0.047%
Net effect after HPC operational (and HPB ceased operation)	+0.011%	-0.020%