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The effect of not fitting an AFD system at HPC on the operation of the HPC FRR systems

The effect of not fitting an AFD system at HPC on the operation of the HPC FRR systems

Brian Robinson

Version and Quality Control

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Executive Summary

As a result of direct cooling of Hinkley Point C (HPC) with seawater, fish present at the intakes will be impinged and subsequently returned to the sea via the Fish Recovery and Return (FRR) system. The fate of the discharged fish will depend upon the species. Sprat are expected to have 100% mortality within the FRR system but demersal fish such as whiting and mullet have an expected mortality of approximately 50% and benthic species such as eels, rockling, some flatfish and crustacea only 20% (BEEMS Technical Report TR456).

Most fish impingement at Hinkley Point takes place from November – January (BEEMS Technical Report TR456) corresponding to the period when 99% of sprat impingement occurs. In the BEEMS Comprehensive Impingement Monitoring Programme (CIMP) data record this peak period was from 19 November 2009 to 14 January 2010. During this peak period sprat accounted for 76% of total fish impingement at HPB, the remainder being predominantly whiting (16%), with some mullet (3%) and small numbers of other species. All of the sprat are expected to suffer 100% mortality in the HPC cooling water (CW) system. The question that then arises is whether these large sprat impingement events will affect the efficiency of the FRR system and reduce the survival of the other species impinged.

The HPC CW design from intake to FRR outfall is detailed in NNB Genco 2017 and has been examined to determine where fish density would be the greatest for the longest period of time. In most parts of the circuit impinged fish are transported in large, increasing volumes of water where the density is far below the safe density threshold. The drum screen and band screen buckets stand out as the highest risk areas where fish densities will be the highest and has, therefore, been the focus of this study.

All of the calculations in this report are based upon an assumption of HPC fitted with LVSE intakes but no Acoustic Fish Deterrent (AFD) system. Results are also presented for completeness for HPC with no LVSE intakes fitted.

Results and Conclusions

Using the peak impingement loadings for HPC with Low Velocity Side Entry (LVSE) intakes fitted the peak fish density in the drum screen buckets is predicted to be 4.3% of the safe transport threshold of 100g/l. That threshold is based upon 1 hour transport. In practice transport times in the HPC drum screen fish buckets will be a maximum of 8 minutes and the threshold used is, therefore, highly precautionary.

The equivalent calculation for band screens at HPC with LVSE intakes fitted shows a peak density of 0.7% of the safe 100g/l threshold. That threshold is based upon 1 hour transport. In practice transport times in the HPC band screen fish buckets will be less than 50 minutes.

The effects of interannual variation in sprat impingement was considered by examination of the HPB Routine Impingement Monitoring Programme (RIMP) dataset from 2000/01 to 2016/17 (Appendix A). The CIMP year had the 3rd highest sprat impingement numbers in that period and the highest impingement year recorded an increase of 1.6 fold over that in the CIMP year. Applying that factor, the predicted peak fish density in the HPC drum screen buckets would be 7.1% of the safe 100g/l threshold and 1.1% in the band screen buckets.

The effect of hourly variation in impingement loadings has also been considered and found to increase the predicted HPC peak fish densities by a factor of 2.8 to 3.1 during a one hour period on one day. During that one hour period, the peak fish density at HPC would be 13% of the safe threshold and therefore still negligible.

These fish densities are well below what are precautionary thresholds and there is, therefore, confidence that the peak winter periods of impingement at HPC with no AFD fitted would not cause the FRR efficiency to reduce from that assumed in TR456.

1 Introduction

As a result of the direct cooling of the Hinkley Point C (HPC) power station with seawater, fish will be impinged through the cooling water (CW) infrastructure. To avoid fish, invertebrates and other debris passing into the station condensers, cooling water from the intakes passes through rotating drum or band screens. Fish and invertebrates are washed from the screens and are returned to sea via the Fish Recovery and Return (FRR) outfall.

Most fish impingement at Hinkley Point takes place in winter from November – January (BEEMS Technical Report TR456) corresponding to the period when 99% of sprat impingement occurs (Figure 1). In the CIMP data record this peak period was from 19 November 2009 to 14 January 2010. If the window was widened to 13th November to 28th January, the total sprat impingement numbers only increased by 3%. During this peak period sprat accounted for 76% of total fish impingement at HPB, the remainder being predominantly whiting (16%), with some mullet (3%) and small numbers of other species. In addition, large numbers of shrimps (grey, pink and ghost) were impinged throughout the year. Figure 2 shows the calculated impingement weight per 24 hours from measurements made during the CIMP programme.

At HPC all of the impinged fish and crustacea will be recovered in the FRR system and returned to sea via the dedicated subtidal FRR outfall. Delicate pelagic species such as sprat are expected to have 100% mortality within the FRR system but demersal species such as whiting and mullet and benthic species such as eels, rockling, flatfish and crustacea are more robust and have expected mortalities of approximately 50% and 20% respectively (TR456).

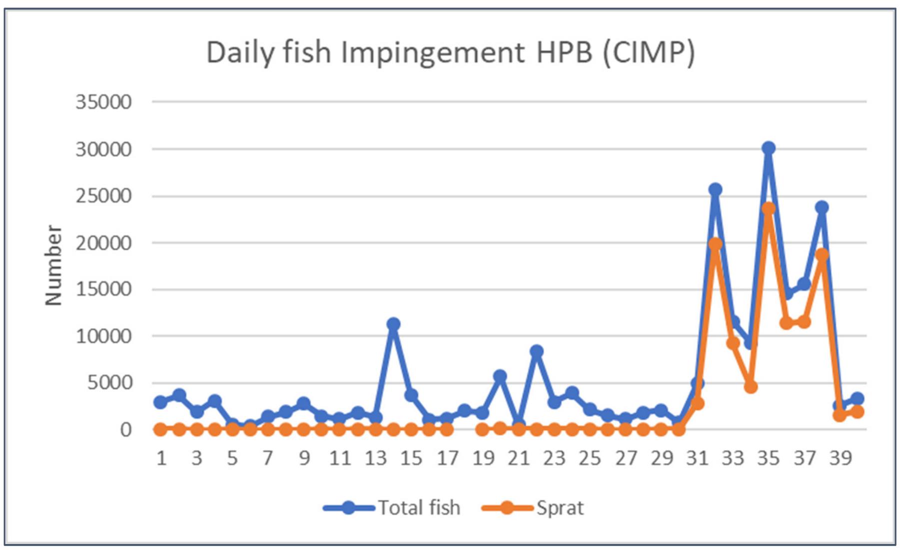

Figure 1 Measured daily fish impingement at HPB during the period February 2009 to end January 2010 (The horizontal axis is the measurement day in the 40 * 24-hour measurement periods in the programme)

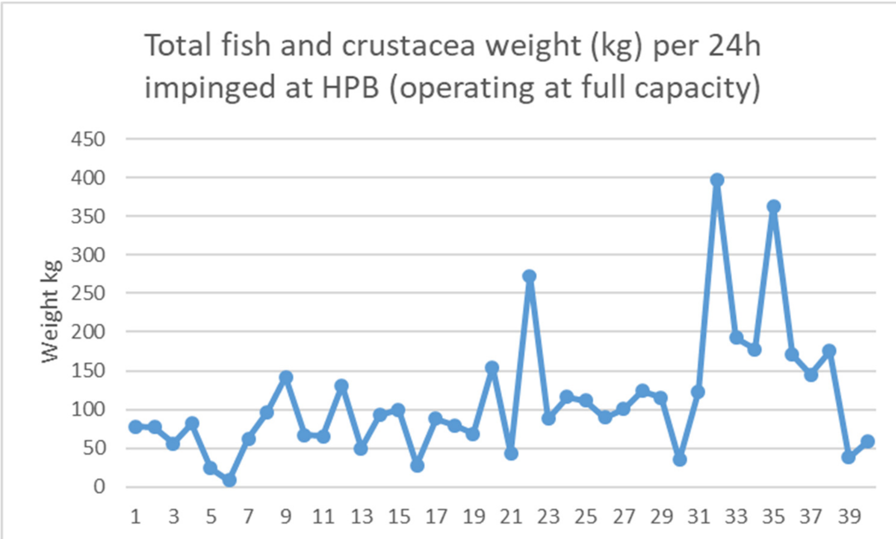

Figure 2 Impingement weight per 24 hours at HPB during the period February 2009 to January 2010.

Over the full CIMP sampling year the average weight of fish and crustacea per 24hours impinged at HPB was 112 kg/day or 85.8 kg/day outside of the peak sprat period of 13 November to 14 January and 218 kg/day in the peak sprat period.

The largest 24 hour impingement weights at HPB were on 19 November 2009 and 17th December 2009 and were 398 kg/day and 363 kg/day respectively. Both of these dates occurred when exceptionally large numbers of sprat were impinged.

The dominant species on those two days are shown in Table 1 and Table 2.

Table 1 HPB Impingement loadings calculated from CIMP measurements on 19 November 2009

Species	kg/24h	Number/24h
sprat	198.3	19,885
whiting	73.7	4,288
thin lipped grey mullet	14.0	97
5 bearded rockling	6.2	259
cod	25.5	419
conger	16.1	4
ghost shrimp	7.3	9,680
grey shrimp	28.1	19,788
pink shrimp	17.4	9,463
Sub total	386.6	63,882
Total fish + crustacea	397.8	

Table 2 HPB Impingement loadings calculated from CIMP measurements on 17 December 2009

Species	kg/24h	Number/24h
sprat	140.2	23,616
whiting	84.8	4,389
thin lipped grey mullet	7.7	1,157
5 bearded rockling	14.6	512
cod	16.8	240
bass	10.2	32
conger	63.7	21
grey shrimp	22.0	10,851
Sub total	359.9	40,818
Total fish + crustacea	362.9	

On both days the dominant species were sprat followed by whiting and shrimp.

1.1 Predicted HPC Impingement levels

The method of predicting HPC impingement from HPB CIMP results is explained in BEEMS Technical Report TR456. Briefly it consists of

1. Raising HPB impingement numbers (and weights) by the ratio of the cooling water flows (131.86/33.7 cumecs = 3.913)

2. Multiplying by the calculated impingement reduction factors due to the design of the HPC intake heads (TR456) of 0.646 for all species except pelagic species and 0.2455 for pelagic species (e.g. sprat, herring)

Applying these factors to the 19th November and 17 December results in predicted HPC impingement weights of 695 kg/24h (Table 3) and 698 kg/24h (Table 4) respectively. For completeness the HPC impingement weights and fish numbers are also shown in these tables for an unmitigated HPC (i.e. without LVSE intakes).

Table 3 Predictions for HPC Impingement based upon 19 November 2009 CIMP data

Species	Unmitigated HPC Kg/24h	Unmitigated HPC Number/24h	HPC with LVSE intake kg/24h	HPC with LVSE intake Number/24h
sprat	775.8	77,805	190.5	19,101.2
whiting	288.2	16,778	186.2	10,838.5
thin lipped grey mullet	54.7	379	35.4	244.7
5 bearded rockling	24.4	1,013	15.8	654.7
cod	99.6	1,638	64.4	1,057.9
conger	63.0	16	40.7	10.1
ghost shrimp	28.6	37,876	18.5	24,467.6
grey shrimp	110.1	77,426	71.1	50,017.0
pink shrimp	68.2	37,026	44.0	23,919.1
Sub total	1,512.6	249,956	666	130,311
Total fish + crustacea	1,556.4		694.7	

Table 4 Predictions for HPC Impingement based upon 17 December 2009 CIMP data

Species	Unmitigated HPC Kg/24h	Unmitigated HPC Number/24h	HPC with LVSE intake kg/24h	HPC with LVSE intake Number/24h
sprat	548.5	92,404	134.6	22,685
whiting	331.8	17,173	214.3	11,094
thin lipped grey mullet	30.0	4,527	19.4	2,924
5 bearded rockling	57.1	2,003	36.9	1,294
cod	65.8	939	42.5	607
bass	39.9	125	25.8	81
conger	249.4	83	161.1	54
grey shrimp	85.9	42,457	55.5	27,427
Sub total	1,408.3	159,712	690.1	66,166
Total fish + crustacea	1,420.1		697.7	

2 Effect of increasing the density of fish in the HPC Cooling Water system

The HPC 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 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 Low Velocity Side Entry (LVSE) heads or Acoustic Fish Deterrents (AFDs). The HPC 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 most coastal stations is from seaweed or more occasionally jellyfish inundations but some stations in the southern North Sea have experienced operational issues from exceptionally large winter sprat shoals. The HPC filtration systems have been dimensioned such that sprat shoals are not considered likely to create operational problems for the system. The focus of this report is, therefore, to assess whether increased fish density during the winter period at HPC will have any significant effect on fish survival in the CW system.

When fish are constrained in small volumes of water for prolonged periods of time (e.g. for >1hour depending on numbers of fish) mortality can increase due to lack of dissolved oxygen. There is a large volume of empirical data on this subject from the extensive trade in live fish (commercial and ornamental species). The single most important factor for survival is maintaining sufficient dissolved oxygen to support the fish respiration requirements and the crucial factors underlying oxygen consumption have been found to be fish weight (in terms of grams per litre) and water temperature. For example, when water temperature increases from 10°C to 20°C oxygen consumption is doubled. (Berka 1986). This is compounded by reduced solubility of oxygen in water with increasing temperature, i.e. there is less dissolved oxygen available. However, sprat inundations at Hinkley Point take place from mid-November to the end of January when seawater temperatures are typically in the range 5°C to less than 10°C.

The density thresholds established from transport studies take account of a large range of factors. For example, fish being transported are stressed and their oxygen consumption is higher than normal, large fish consume less oxygen per unit weight than small fish and dead fish compete with live fish for oxygen (Berka 1986). Most transport studies are focused on typical journey times of 4 to 24 hours in a fixed volume of water but data on safe fish densities are available for transport times down to 1 hour duration. These density thresholds are in effect integrations of the impacts of being confined in constant small volumes of water on fish survival. In contrast, when fish are constrained in tanks of continuously refreshed water (e.g. recirculation systems) or as at HPC in very large volumes of moving seawater where the volume of water increases as the fish are flushed through the CW system the expected risk to survival is very low. However, when fish are being transported in the drum and band screen buckets at HPC before being discharged into the larger, flowing volume fish collection gutters, they will be constrained in small volumes of water. This is the period of greatest fish density in the whole plant and therefore the focus for this study.

2.1 Acceptable fish densities from fish transport studies

Safe storage densities expressed as grams/litre vary with species, temperature and fish size with smaller fish needing proportionately more oxygen per unit mass than larger fish. Making the conservative assumption that fish at Hinkley Point weigh 5g each (in fact impinged sprat are the most abundant small fish with a mean weight of typically 6-10g in winter) and that water temperatures are 10°C (in fact they are 5 to <10°C), published review data (Berka 1986) indicates that typical safe stocking densities for such sized fish at temperatures of 10°C are approximately 50 to 190g/l for transport durations in the range 5-12h (the lowest thresholds are based upon the most sensitive species of brown trout and salmon and are selected to achieve less than 1% mortality). Interpretation of these transport studies has to be undertaken with caution because they are only analogues of fish transport within HPC. The published thresholds are mostly based upon freshwater species but the same numbers are also used for marine species e.g. striped bass (data from Aquaneering Inc. 25/6/2019). The thresholds are also based upon fish transport in sealed oxygen filled bags for extended periods of time; usually up to 12h. For the much shorter transport times in the fish buckets at HPC oxygen consumption will be much reduced and provided that the predicted fish densities do not exceed the threshold, there is not a concern about the replacement of oxygen in the fish buckets.

At Hinkley Point the concern over fish survival is about demersal and robust benthic species not pelagic species which are not expected to survive passage through the FRR system under any conditions. At a reduced 1h transport duration the density threshold would translate to a minimum safe limit of approximately 100g/l using data from Berka 1986. For tiger prawns in the 3-4g range the safe stocking density is reported to be 90-120g/l. Shrimp at Hinkley Point are approximately half that weight and so 100g/l would also be a conservative threshold for the common shrimp species at Hinkley Point.

2.2 Comparison of peak fish and crustacea densities in HPC with safe thresholds

The HPC CW design from intake to FRR outfall is detailed in NNB Genco 2017 and has been examined to determine where fish density would be the greatest for the longest period of time. In most parts of the circuit impinged fish are transported in large, increasing volumes of water where the density is far below the safe threshold. The drum screen and band screen buckets stand out as the highest risk areas where fish densities will be the highest.

The drum screens filter 91% of the total HPC cooling water flow and the band screens filter the remaining 9%.

2.2.1 Drum screens

There are 4 drum screens at HPC, each has 56 pairs of buckets i.e. a total of 112 buckets. The amount of water held in each bucket and the fish transport times at different tidal states are detailed in Table 5 (from NNB GenCo 2017).

Table 5 Description of water volumes in drum screen buckets

Tidal State	Seawater volume retained in fish buckets from leaving the water surface to tipping the fish into the collection gutters	Transport time at normal rotation sped of 2.5m min^{-1} from leaving the water surface to tipping the fish into the collection gutters
Lowest Astronomical Tide	9l to 7.7l	8 minutes
Mid tide	99l to 7.9l	4.8 minutes
Highest Astronomical Tide	34l to 7.9l	1.7minutes

For the purposes of the calculations in this report, a water volume of 7.7l has been assumed, recognising that, in reality, fish will be transported in larger volumes at most times and therefore at lower density. The drum screen transport times are also much lower than the 1h used to select the safe transport threshold but the threshold has not been rescaled and is, therefore, a precautionary figure.

2.2.2 Band screens

There are 4 band screens at HPC with 83 fish buckets on each screen. The water held in the band screen bucket is 20l and does not vary with the state of the tide. The band screens will rotate continuously at 0.5m min^{-1} (an adaptation specifically incorporated to improve fish survival (NNB GenCo, 2017), but can be increased to 10 and 20m min^{-1} during periods of high clogging. One full rotation at normal speed (0.5m min^{-1}) takes approximately 100 minutes, but the maximum amount of time fish are in the bucket (from emergence from the water to discharge to the fish collection gutter) is 40 minutes (NNB GenCo, 2017). Fish in the collection gutters are flushed through the FRR system with large quantities of fresh seawater.

3 Results

The calculated peak fish impingement weights during the entire CIMP programme have been used to calculate the peak fish density in the drum screen buckets. The HPC peak predicted impingement loadings detailed in Table 3 and Table 4 are not substantially different and so the calculations in this report have used the maximum loading of 698 kg/24h from Table 4.

Table 6 shows that for HPC with LVSE intakes the peak fish density in the drum screen buckets is 4.3% of the safe 100g/l threshold for 1 hour transport. In fact, the transport times in the drum screen buckets are only 1.7 to 8 minutes and so the threshold used is highly precautionary. The result assuming no LVSE intakes is still only 8.8% (or 9.7% if the 19th November 2019 data from Table 3 are used).

The results of the same calculation for the HPC band screens are shown in Table 7 and show predicted fish densities of 0.7% to 1.3% of the 100g/l threshold in the band screen buckets.

Table 6 Results from the analysis of drum screen impingement at HPC using the peak impingement loadings from the HPB CIMP programme in Table 4.

	HPC impingement weight kg/24h	impingement weight at drum screens kg/24h	impingement weight g/minute	impingement weight/ screen g/minute	fish weight in each bucket g	bucket size l	fish density g/l	% of 100g/l threshold
With LVSE intakes	697.7	634.9	440.93	110.23	33.39	7.7	4.3	4.3%
Without LVSE intakes	1,420.1	1,292.29	897.42	224.36	67.77	7.7	8.8	8.8%

Table 7 Results from the analysis of band screen impingement at HPC using the peak impingement loadings from the HPB CIMP programme in Table 4

HPC	HPC impingement weight kg/24h	impingement weight at band screens kg/24h	impingement weight g/minute	impingement weight/ screen g/minute	fish weight in each bucket g	bucket size l	fish density g/l	% of 100g/l threshold
With LVSE intakes	697.7	62.8	43.61	10.90	13.14	20	0.7	0.7%
Without LVSE intakes	1,420.1	127.81	88.76	22.19	26.73	20	1.3	1.3%

3.1 Impact of interannual variation

These peak densities have been calculated using one year of CIMP impingement data in 2009/10 so it is appropriate to ask how representative that year was for impingement loadings. Sprat shoals cause the most significant increase in winter impingement weights by far at Hinkley Point and changes in sprat numbers have therefore been used as an approximate analogue for increases in total impingement weight. An examination of the Routine Impingement Monitoring Programme (RIMP) dataset for Hinkley Point B over the period 2000/01 to 2016/17 shows that the CIMP year had the 3rd highest sprat impingement numbers in that period with peak sprat impingement in the RIMP programme at 40,744 individuals in 2014/15 compared with 24,920 individuals in 2009/10. I.e. the peak year produced a 1.6 fold increase in sprat impingement compared with the CIMP year used in this assessment. (The sprat impingement in 2014/15 was the largest in the entire 37 year RIMP dataset). Applying the 1.6 factor, the predicted peak fish density in the HPC drum screen buckets would be 7.1% of the 100g/l threshold and 1.1% in the band screen buckets and, therefore, not significant.

3.2 Impact of hourly variation in sprat impingement

Impingement of shoaling species such as sprat is subject to variability and so the peak densities used in the in this report may not represent the absolute peak densities experienced in any particular hour at HPC, The CIMP hourly data was examined to find the absolute maximum sprat density encountered which was from 1 hour on 20 December 2009. The impinged weight in that hour at HPB of 46.7kg/h represented a 2.8 to 3.1 fold increase over the impinged weights at HPB on 17 December 2009 and 19th November 2009 of 15.1 and 16.6kg/h. Using this one hour weight the peak impingement at HPC would be 13.3 g/l for that 1 hour period or 13% of the safe threshold which is still negligible given the short time spent in the drum screen baskets and the short nature of the impingement event.

4 Conclusions

Using the peak impingement loadings for HPC with LVSE intakes fitted the peak fish density in the drum screen buckets was 4.3% of the safe transport threshold of 100g/l. That threshold is based upon 1 hour transport. In practice transport times in the HPC drum screen fish buckets will be a maximum of 8 minutes and the threshold used is, therefore, highly precautionary.

The equivalent calculation for band screens at HPC with LVSE intakes fitted shows a peak density of 0.7% of the safe 100g/l threshold. That threshold is based upon 1 hour transport. In practice transport times in the HPC band screen fish buckets will be less than 40 minutes.

The effects of interannual variation in sprat impingement was considered by examination of the RIMP dataset from 2000/01 to 2016/17. The CIMP year had the 3rd highest sprat impingement numbers in that period and the highest impingement year recorded an increase of 1.6 fold over that in the CIMP year. Applying that factor, the predicted peak fish density in the HPC drum screen buckets would be 7.1% of the safe 100g/l threshold and 1.1% in the band screen buckets. These fish densities are well below what are precautionary thresholds and there is, therefore, confidence that the peak winter periods of impingement at HPC with no AFD fitted would not cause the FRR efficiency to reduce from that assumed in TR456.

The effect of hourly variation in impingement loadings has also been considered and found to increase the predicted HPC peak fish densities by a factor of 2.8 to 3.1 during a one hour period on one day. During that 1 hour period, the peak fish density at HPC would be 13% of the safe threshold and therefore still negligible.

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Appendix A RIMP sprat impingement records

Sprat impingement numbers from the HPB RIMP programme are shown in Table 8.

Table 8 HPB RIMP annual impingement numbers for sprat

Year (February to January)	HPB measured annual impingement numbers
2000/01	13,184
2001/02	5,424
2002/03	7,240
2003/04	7,304
2004/05	8,408
2005/06	11,976
2006/07	4,992
2007/08	10,056
2008/09	17,864
2009/10	24,920
2010/11	5,712
2011/12	16,000
2012/13	12,560
2013/14	16,400
2014/15	40,744
2015/16	25,256
2016/17	18,864