Document title: *Staverton Hydropower Project: Fish Migration Flows*
Status: Final
Date: October 2018
Project Code: *SHCBS IA.PG.19*
Client: *Staverton Hydro Community Benefit Society (SHCBS)*
Produced by: Pete Kibel
QC: Toby Coe

Fishtek Consulting, Unit 1 Webbers Way, Dartington, Devon, TQ9 6JY

Tel: 01803 866680 | www.fishtek-consulting.co.uk

Executive Summary

Staverton Hydro Community Benefit Society (SHCBS) propose to install a single 100 kW Archimedean screw turbine at the downstream end of an existing leat on the River Dart, immediately south of Staverton village, Devon. The leat was initially constructed to power two Kaplan turbines that provided electricity to the Dartington Estate from the 1920’s through to the 1960’s.

The proposed scheme would have a maximum abstraction rate of 6.0 m^3/s. A Q95 hands-off flow (HOF) would be enforced, with a proportional flow take of 50/50 above the HOF. In view of the relatively low maximum abstraction, approximately 40% of the 15 m^3/s (1.3 x Q mean) permitted under best practice guidance, the total abstraction is precautionary even for the most sensitive category of river.

It is important to ensure that fish attempting to migrate upstream are not delayed from doing so by the reduced flow in the river channel. The channel form, velocities and depth in the entire potentially deprived reach (PDR) was assessed at low river flows, equating to Q85/Q90. A map of minimum depths recorded is given in figure 1. It is clear that minimum depths throughout the river reach are above 300mm, generally regarded as a suitable minimum depth for adult salmon migration. Sea trout will generally migrate at shallower depths than salmon.

In addition to the survey of the PDR, a migration index was calculated using data from over 1000 fish collected from the fish counter at Totnes weir, 1km downstream of Staverton. The migration index exceeds 1.0 at a flow just above Q95, demonstrating that adult salmon utilise relatively low flows to migrate and are unlikely to be delayed or inhibited from migrating by the proposed abstraction regime.

It is worth noting that the most significant barrier to fish migration in this section of the river Dart, is the diagonal baulk or easement at Staverton weir. The weir is rapidly being undermined as the pile cap and 10m section of piles adjoining the baulk have collapsed in recent floods. As more and more water flows underneath the piles driven at high velocity by the hydraulic head, the upstream water level at low flows is dropping, and will eventually render the baulk perched, making the weir impassable at low flows. The project proposed by SHCBS aims to mitigate this by building a new best practice Larinier fish pass at the weir, replacing the diagonal baulk and repairing the damaged piles. This would improve fish migration in the lower reaches of the Dart.

Figure 1: Depth profiles for PDR at low flows

1. Migration Index

The HEP project at Totnes weir, 1km downstream of Staverton incorporates a fish counter; data from this counter was used for the 2017 season to derive migration flows and a migration index for salmon.

The analytical approach used was a method of examining the relationship between upstream migration and river flow, described by Solomon *et al.* (1999). This method essentially accounts for the fact that higher river flows (lower Q values such as Q10) are less 'available' than lower flows due to their lower frequency. The method relies on the construction and comparison of cumulative frequency curves of:

- The flows prevailing when fish were recorded migrating ('fish-flows')
- The flows prevailing throughout the period under consideration ('all-flows')

The analysis relies on the comparison of the slopes of these two curves and comparing the instantaneous slope of each across the full range of flows. A series of values of instantaneous slope of each line is determined by integrating the polynomial regression equations and calculating the slope at 0.01 m^3/s intervals.

If the instantaneous slope of the 'fish flows' line is divided by the instantaneous slope of the 'all flows' line a so-called 'index of fish migration' is obtained. A value of 1.0 indicates that the slopes are the same and 'all flows' and 'fish flows' are accumulating at the same rate. A value of less than 1.0 indicates that fish migration is under-represented and a value in excess of 1.0 indicates that fish migration is over-represented. A complete description of the methodology can be found in Solomon *et al.* (1999). This technique was applied for the data on salmon (fish over 500 mm) only.

This approach enables the assessment of river flows that salmon are using to migrate upstream in the lower reaches of the River Dart.

2. Results

Over the period January 2017 to October 2017 a total of over 1800 upstream fish movements were made past the fish counter, of which 1010 were classified as salmon (fish greater than 500mm in length) and 790 as sea trout.

The plot of the cumulative frequency of 'All Flows' and 'Fish Flows' is given below in figure 2. This shows that the graph of Fish Flows is steeper than All Flows from the lowest flow that fish were recorded moving.

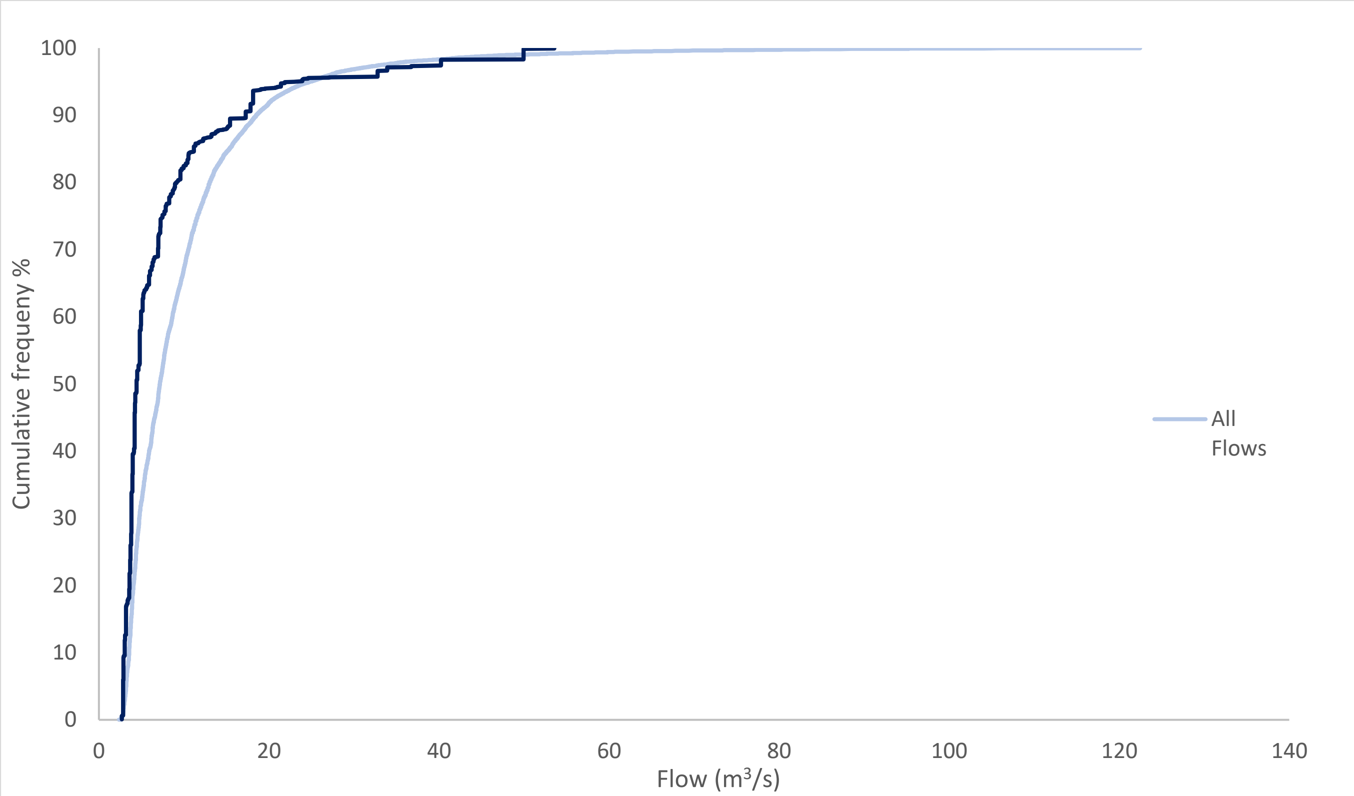

Figure 2: Cumulative frequency of all flows (light blue) and fish flows (dark blue)

Working through the migration index process, the migration index was found to exceed 1 at a flow of 2.30 m^3/s, equal to ~1.3 x Q95.

The evidence that fish are moving at relatively low flows is substantiated by the data in figure 3 below which shows that the majority of fish in the river move at low flows, below 4.5 m^3/s, rather than 2-4 times Q95 (3.5-7m^3s).

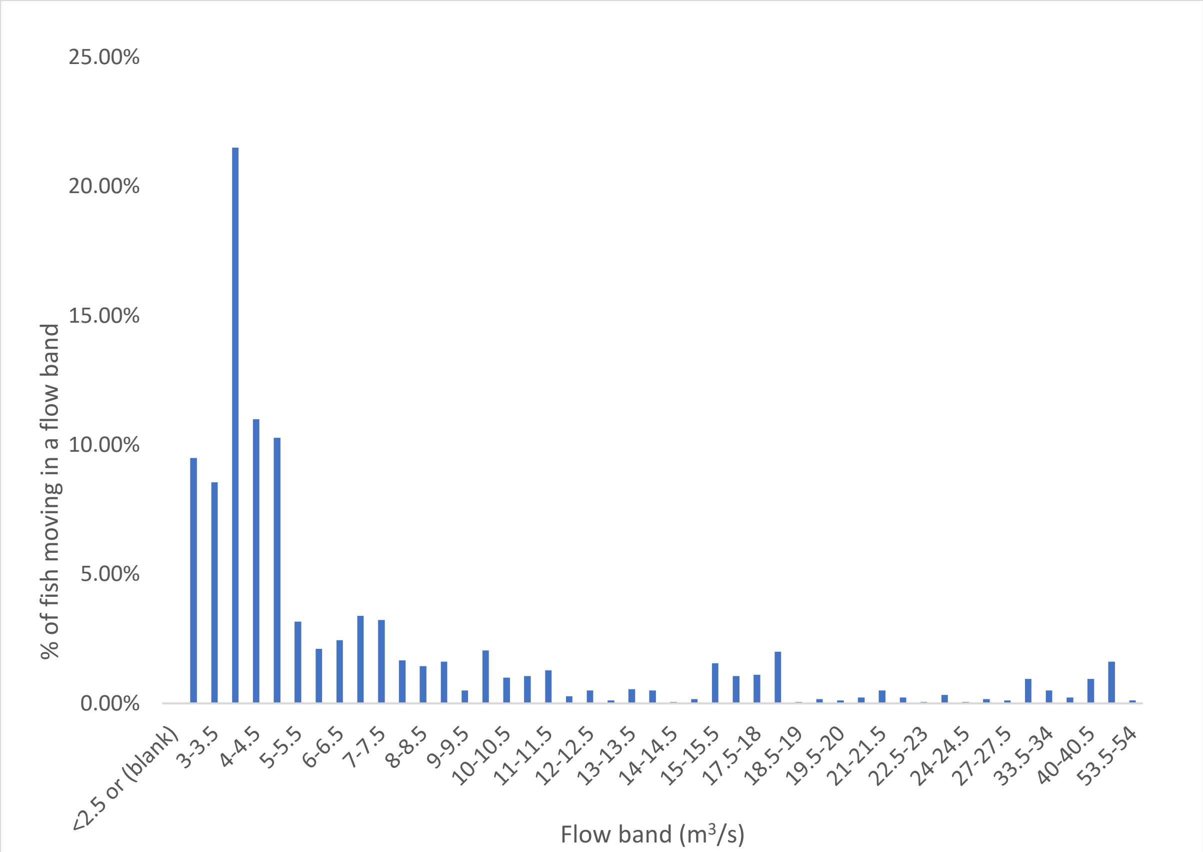

Figure 3: Fish movement vs flow band at Totnes weir

3. Discussion

It is critical that the proposed development does not disrupt the migration of salmonids within the river. A key component of ensuring that this does not occur is the protection of so-called 'migration flows'. These are the river flows that anadromous species such as salmon and sea-trout typically utilise when migrating upstream. These vary from river to river and are a result of a complex interaction between many factors including the river's morphology and hydrology and the genotype and phenotype of the anadromous fish populations within a river.

The triggers to upstream migration are complex and many factors have been found to be a significant predictor in the upstream movement of salmon. These include the state of the tide (Aprahamian, 1998), the time of day (Webb, 1990), temperature (Jensen *et al.*, 1986; Erkinaro *et al.,* 1999) and river discharge (Alabaster, 1970; Banks, 1969; Laughton, 1991). Of the myriad factors affecting salmon migration, river discharge is frequently cited as being the most important factor (Banks, 1969; Solomon *et al.*, 1999). In particular, an increase in river discharge has often found to be associated with upstream migration (Bagliniere *et al.,* 1990; Solomon *et al.*, 1999), however this is not always the case (Thorstad and Heggberget, 1988).

An extensive study conducted on six rivers in the South-West found that the river flow that triggered an increase in upstream migration differed depending on the specific river in question, as well as the specific longitudinal location within a river (Solomon *et al*., 1999). Significant effects on upstream migration occurred at increasingly higher flows (expressed as an exceedance value), the higher up a river system the fish were located. For example, in the lower reaches of rivers, within a few km of the tidal limit, salmon migration was generally triggered at flows 1-2 times Q95.

This was found to be the case in the lower reaches of the River Dart, where salmon migration was triggered at relatively low flows of Q95 and generally below 3 x Q95. Fish are triggered to migrate by a subtle mix of physio/chemical properties of the water, rather than the volume of discharge. A fish cannot determine the volume of flow, but only the properties of the water in the immediate vicinity of the fish. When fish are stimulated to migrate and pass through a fish pass for example, the pass is discharging a small proportion of the total flow (perhaps less then Q95), but the fish still migrates through the pass. In this sense, if fish are stimulated to migrate in the Dart because the river water has the correct mix of stimulatory factors, then as long as they are not physically prevented from migrating by shallow depth or high velocities, they should not be impeded from migrating. It is clear from the PDR assessment at Staverton that there is a continuous minimum depth for migration (>300mm) throughout the migration flows. Therefore, it is very unlikely that the proposed flow split and HOF would delay upstream migration of salmonids.

If the project goes ahead, it is recommended that a new Larinier fish pass is built at Staverton weir, as this will mitigate the issue around the collapse of the piles and reduced flow in the diagonal baulk and should lead to an overall improvement in fish migration.

Monitoring fish migration using in stream cameras within the new Larinier fish pass would be useful to confirm that fish are not being delayed. It would be straightforward to compare fish movements with turbine on and off periods during migration flows over a 2-3-month window.

4. References

Alabaster, J.S. (1970) River flow and upstream movement and catch of migratory salmonids. *Journal of Fish Biology*, **2**: 1-13

Aprahamian, M.W., Jones, G.O. and Gough, P.J. (1998) Movement of adult Atlantic salmon in the Usk estuary, Wales. *Journal of Fish Biology*, **53**: 221-225

Arthington, A.H., Bunn, S.E., Poff, N.L., Naiman, R.J. (2006) The challenge of providing environmental flow rules to sustain river ecosystems. *Ecological Applications*,**16**: 1311–1318.

Baglinière, J. L., G. Maisse & A. Nihouarn (1990) Migratory and reproductive behaviour of female adult Atlantic salmon, *Salmo salar* L., in a spawning stream. *Journal of Fish Biology*, **36**: 511–520

Banks, J. W. (1969) A review of the literature on the upstream migration of adult salmonids. *Journal of Fish Biology* **1,** 85–136

Everest, F.H., Sedell, R., Reeves, G.H. and Wolf, J. (1985) Fisheries enhancement in the Fish Creek basin - an evaluation of in-channel and off-channel projects, 1984. *U.S. Dept. of Energy, Bonneville Power Administration, Division of Fish and Wildlife, Portland, OR. 228 p.*

Finstad, A.G., Okland, F., Thorstad, E.B.and Heggberget, T.G. (2005) Comparing upriver spawning migration of Atlantic salmon (*Salmo salar*) and sea trout (*Salmo trutta*). *Journal of Fish Biology*, **67**: 919-930

Gibson, R.J. (1993) The Atlantic salmon in fresh water: spawning, rearing and production. *Reviews in Fish Biology and Fisheries*, **3**: 39-73

Hendry, K., Sambrook, H., Waterfall, R. (2007) Assessment of salmon stocks and the use of management targets; a case study of the River Tamar, England. *Fisheries Management and Ecology*, **14**: 7-19

Jensen, A.J., Heggberget, T.G., Johnsen, B.O. (1986) Upstream migration of adult Atlantic salmon, *Salmo salar* L., in the River Vefsna, northern Norway. *Journal of Fish Biology*, **29**: 459-465

L'Abée-Lund, J.H., Vøllestad, L.A. and Beldring, S. (2004) Spatial and temporal variation in the grilse proportion of Atlantic salmon in Norwegian rivers. *Transactions of the American Fisheries Society*, 133: 743-761

Laine, A., Jokivirta, T. and Katopodis, C. (2002) Atlantic salmon, *Salmo salar* L., and sea trout, *Salmo trutta* L., passage in a regulated northern river – fishway efficiency, fish entrance and environmental factors. *Fisheries Management and Ecology*, **9**: 65-77

Laughton, R. (1991) The movements of adult Atlantic salmon (*Salmo salar* L.) in the River Spey as determined by radio telemetry during 1988 and 1989. *Scottish Fisheries Research Report* **50**

Milner, N.J., Elliott, J.M., Armstrong, J.D., Gardiner, R., Welton, J.S. and Ladle, M. (2003) The natural control of salmon and trout populations in streams. *Fisheries Research*, **62**: 111-125

Potter, E.C.E. (1988) Movements of Atlantic salmon, *Salmo salar* L., in an estuary in south-west England. *Journal of Fish Biology* **33** (Suppl. A),153-159

Quinn, T.P., McGinnity, P. and Cross, T.F. (2006) Long-term declines in body size and shifts in run timing of Atlantic salmon in Ireland. *Journal of Fish Biology*, **68**: 1713-1730

Smith, G.W., Smith, I.P. and Armstrong, S.M. (1994) The relationship between river flow and entry to the Aberdeenshire Dee by returning adult Atlantic salmon. *Journal of Fish Biology*, **45**: 953-960

Solomon, D.J., Sambrook, H.T. and Broad, K.J. (1999) Salmon migration and river flow: results of tracking radio tagged salmon in six rivers in South West England. *Environment Agency Research and Development Publication 4*

Thorstad, E.B. and Heggberget, T.G. (1998) Migration of adult Atlantic salmon (*Salmo salar*); the effects of artificial freshets. *Hydrobiologia*, **371/372**: 339-346

Webb, J. (1990) The movements of adult Atlantic salmon in the River Tay and Tummel to Pitlochry Dam. *Scottish Fisheries Research Report*, **48**