Fish passage: don't forget the little guys!

Mike Forty described his studies into the efficiency of different types of fish pass

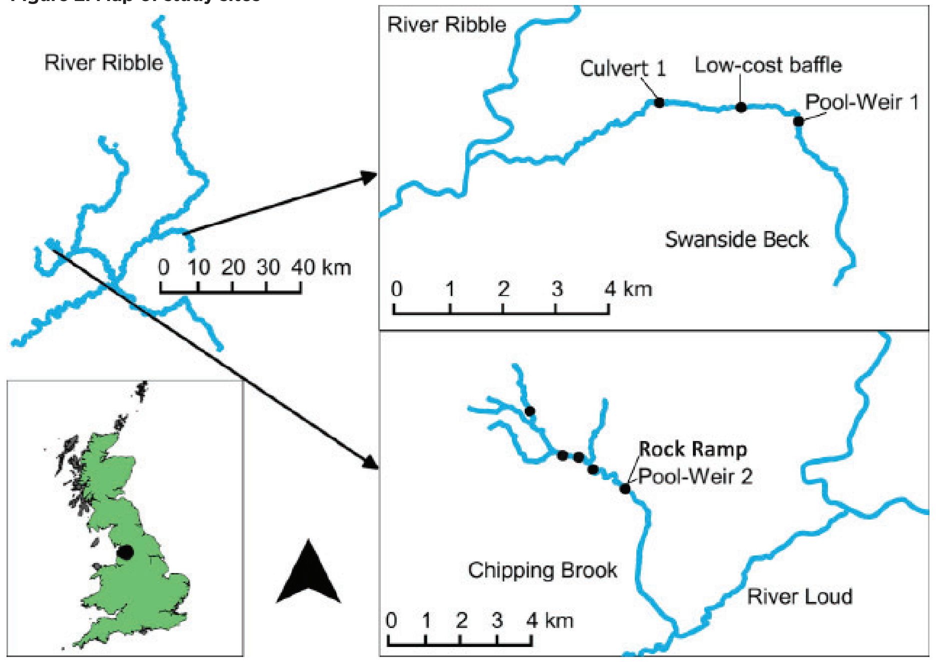
Over the past three years, I've been lucky enough that my Ph.D. studies have allowed me to get up close and personal with one of the great freshwater fishes, the brown trout (*Salmo trutta*, Fig. 1). This marvellous creature, enjoyed by so many, has endured despite often residing in watercourses that have been used and abused by human society, such that now those watercourses are riddled with the remnants of the Industrial Revolution in the form of impoundments. While impoundments such as weirs and dams were important catalysts in industrial progress (providing services to power mills or for drinking water storage), many of the low-head structures (< 3m head height) are now redundant leaving only the legacy of their physical presence to pose a threat to migratory fish species.

A recent count of 25,000 migration barriers on UK rivers (Gough *et al.*, 2012) highlights the scale of this issue. The impacts of migration barriers vary in severity as much as the physical characteristics of the structures themselves; from forming a complete barrier and isolating entire river sections to allowing most fish to pass through. Barrier impacts can also take an insidious form, with fish spending large amounts of time negotiating structures thereby reducing their fitness through wasted energy and increased exposure to predation (eg from piscivorous birds). Ultimately, these impacts can lead to a reduction in population size as well as fitness. Today, the situation is being ameliorated through the development and implementation of a plethora of fish passage technologies, which come in a range of technical and nature-like designs, both aimed at improving the porosity (to fish) of in-stream barriers. Despite the increased implementation of fish passage projects, there is still a paucity in the knowledge of the true effectiveness of different designs for each species of migratory fish (Bunt *et al.*, 2012).

Salmo trutta migrates in both its resident 'brown trout' (potadromous) and 'sea trout' (anadromous) forms, both up and downstream, and throughout most ages/life stages, with free passage being a vital component in life-cycle completion. For upstream migrations (the focus of my research), free passage can be required for spawning, recovery from displacement after disturbance events, resource seeking, or seasonal distribution shifts (Baras and Lucas, 2001). While the focus has often been on the need for passage of large adult trout, it is also a requirement for juveniles which can migrate for those same reasons. This even includes spawning whereby sexually mature parr can contribute towards population survival through alternative spawning strategies (eg precocious males; Garcia-Vazquez *et al.*, 2001).


Figure 1. Brown trout

Figure 2. Map of study sites



The project I have been working on at Durham University with the Ribble Rivers Trust has been investigating the effectiveness of a range of recently installed fish easements* on low-head structures in spawning tributaries of the River Ribble catchment (NW England), for both adult and juvenile brown trout. Five structures were evaluated on two study streams across summer and autumn 2013 and 2014; Swanside Beck and Chipping Brook (Fig. 2). Both streams are 5-10 metres wide with recovering populations of brown trout (both resident and anadromous components) and Atlantic salmon. Two pool-weir type fish passes (PW1 and PW2), one low-cost baffle pass (LCB), (Servais, 2006), and one embedded rock ramp (ERR) (Fig. 3) were evaluated, with a 20-metre culvert under a railway bridge used as a control representing a man-made structure within expected swimming performance of brown trout (mean velocity at base flow 0.46 ms-1).

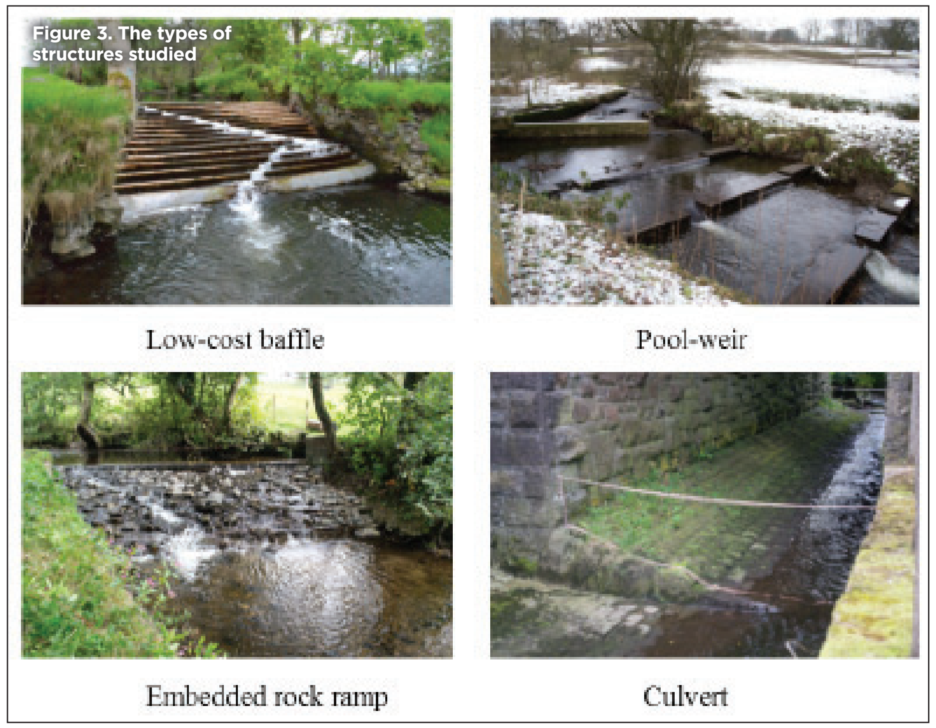


Figure 3. The types of structures studied

Structure performance was determined using three measures: passage efficiency (the percentage of fish successfully ascending a structure compared to those attempting it); attraction efficiency (the percentage of fish attempting a structure of those tagged and displaced below it); and delay (the amount of time between a fish first being detected attempting and its successful passage). In addition, we utilised the data we captured to construct binary logistic regression models to investigate the probability of a fish's successful ascent based on its size (fork-length).

Passage data were collected using Passive Integrated Transponder (PIT) telemetry which involved the placement of two antennae loops across the width of the river at the upstream and downstream extents of the structures. This design allowed us to determine which direction a tagged fish was travelling, whether it attempted to pass upstream and if it was successful, and the amount of time a fish was delayed before successful passage. Fish were tagged with a PIT tag inserted via a small incision into the peritoneal cavity, meaning that each tag would send information to the data logger when the fish passed through the field of the antennae. The experiment was conducted in two parts: tagging naturally migrating trout downstream of structures and also groups from above structures which were then displaced 100 metres downstream. This second group utilised the homing instinct of resident trout prompting them to attempt the structure in order to return to their home range.

We identified that on both study streams a sizeable proportion (ca. 30%) of non-displaced trout parr exhibited upstream movement during the autumn migration period, with a number of individuals passing through multiple structures to reaches upstream. The models predicting passage probability based on length ($P < 0.05$; Fig. 4) indicated that pool-type fish passes were most effective for both smaller and larger trout, with fish lengths for both 50% and 90% probability of upstream passage ($P50 \leq 100$mm and $P90 \leq 200$mm) being slightly lower than the low-cost baffle pass. Reasons for this difference in structure performance are likely driven by the higher flow velocities experienced in the low-cost baffle pass, along with a lack of resting places like those found in pool-type passes. However, it was remarkable to see the similarity in performance between the two types of structures given the difference in gradients to overcome (24% for low-cost baffle vs 12% for pool-weir and rock ramp designs). The observed increase in passage probability for larger fishes was in keeping with our expectations, as swimming ability is known to increase with body length (Beamish, 1978).

The relatively untested low-cost baffle design provided further evidence of good performance with passage efficiencies similar to other designs in both years of the study (Table 1). All designs exhibited greater than 65% passage efficiency. However, a difference in performance was observed between the fish pass designs and the control culvert which passed all (or nearly all) of fish attempting it in both years (Table 1) with minimal delays (Fig. 5). As a great demonstration of the benefit of post-project monitoring, one pool-weir structure (PW2) was observed to pass a large proportion of trout (71%), but delays incurred before passage were extremely high (median 108.3 hours) compared with the other designs (Fig. 5). Upon further investigation, construction anomalies in pool head heights were found which were corrected in 2014. Following on from this adjustment, the benefits were immediately evident, with delay reduced to under three hours in line with other structures.

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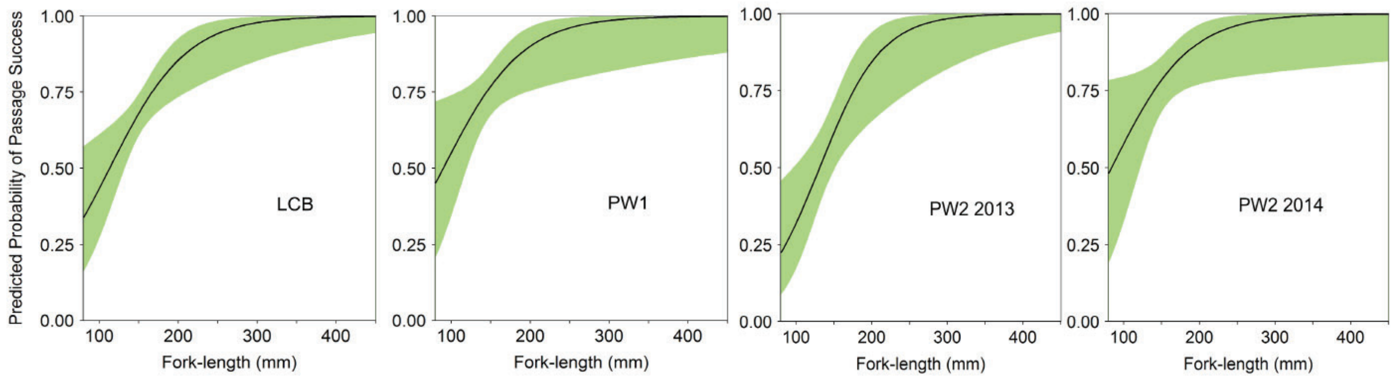

Figure 4. Binary logistic regression models of predicted probability of passage based on fork-length

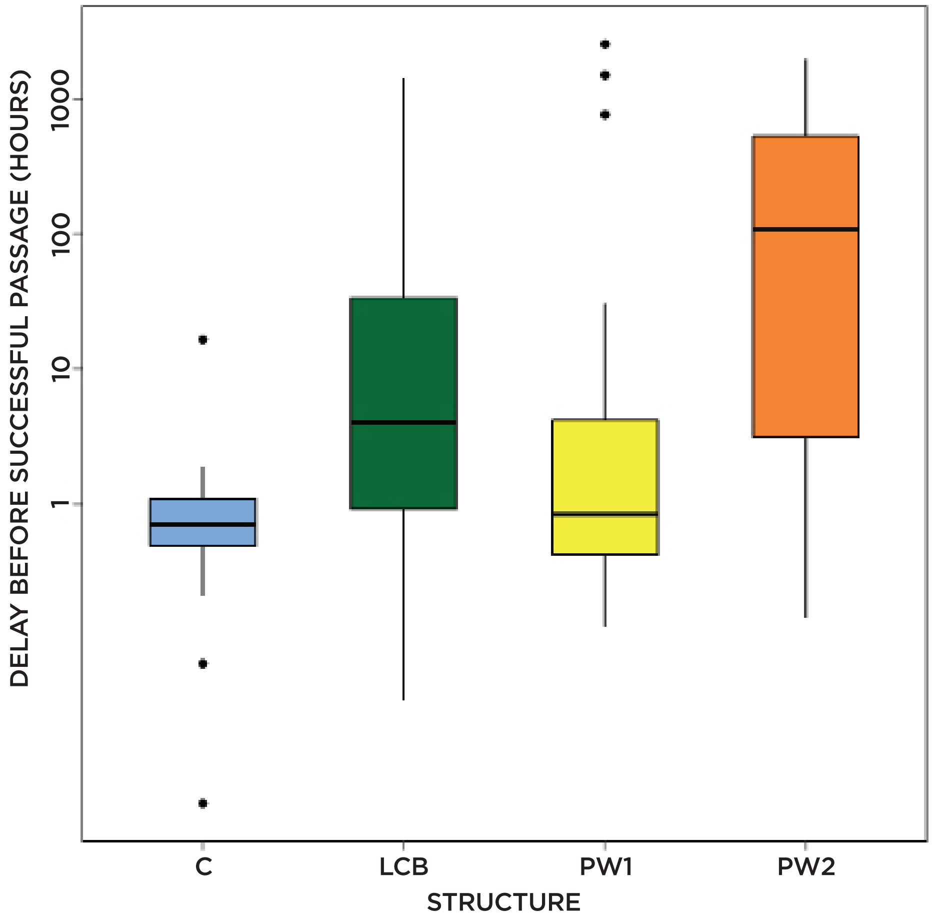

Figure 5. Boxplots of delay before successful passage in 2013

We found that the fish displacement method used in this study was highly effective, with large proportions of trout being motivated to attempt to pass upstream (up to 88% in 15 days). The majority of those that did so also appeared to move within the first few days following their displacement, making it a potentially useful tool to combine with telemetry for rapid assessment of the barrier impact of a structure and the efficacy of different fish pass designs. In essence, the method could be really useful when attempting to prioritise where fish passage works would be most beneficial or to evaluate the suitability of different designs.

The variation we observed in the performance of different fish pass designs, particularly for smaller individuals, is of particularl interest when put into context of the substantial proportion of trout parr which were demonstrating upstream movement during the spawning period. Facilitating the more efficient passage of trout (and other fish species) in terms of numbers, reduced delay, and a larger range of sizes could aid in spawning success and ultimately benefit population numbers, fitness and resilience. This can be achieved not only by addressing in-stream barriers to migration by removal or installing fish passes, but also by ensuring passage designs are optimised and suitable for the range of species and sizes which require free passage. Let's not forget the little guys!

Mike Forty currently works part-time for the Ribble Rivers Trust while finishing his Ph.D. in River Restoration Ecology at Durham University under the supervision of Dr. Martyn Lucas and Jack Spees (Director, Ribble Rivers Trust). This work was funded by a DEFRA Catchment Restoration Fund grant.

*easements are fish passage improvements which are retro-fitted to existing barriers and are of much lower cost than specifically designed and engineered fish passes.

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Table 1. Passage success of displaced Salmo trutta within 15 days in 2013 and 2014.

	2013				2014			
Structure type	**C**	**LCB**	**PW1***	**PW2***	**C**	**LCB**	**PW2**	**ERR**
Passage efficiency (%)	**100**	**67**	**79**	**71**	**96**	**82**	**79**	**71**
Attraction efficiency (%)	**37**	**73**	**66**	**37**	**49**	**88**	**87**	**71**

***Minimum estimates of attempts, passage efficiency and attraction efficiency due to 4-day (26% of total experiment duration) periods of equipment failure shortly after fish displacement**

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