River Wye, Litton Mill Leat & Adjacent River: Advisory Visit

	River Wye: Litton Mill to Cressbrook Mill
River	Wye (Derbyshire)
Waterbody Name	River Wye from Monk's Dale to River Derwent
Waterbody ID	**GB104028057820**
Management Catchment	Derwent Derbyshire
River Basin District	Humber
Current Ecological Quality	Moderate
U/S Grid Ref inspected	SK1600672973
D/S Grid Ref inspected	SK1707572908
Length of river inspected	1.5 km (plus 330 m of Mill Leat)

Wild Trout Trust Report – Following a Site Visit on 19/10/2017

1. Introduction

A site visit and habitat appraisal was carried out at the request of Don Stazicker (fishery officer for the Cressbrook & Litton Fly Fishers' Club) and Karen Joseph (land-owner for the Mill Leat within the surveyed reach). Habitat was examined along the Mill Leat (approx. 330 m) and along the main river channel from Litton Mill downstream to the impounded lake above Cressbrook Mill weir. The surveyed reaches fall within a single Water Framework Directive (WFD) waterbody - River Wye, Monk's Dale to River Derwent (**GB104028057820**). More information on the classification of this waterbody can be found on the following web page: (http://environment.data.gov.uk/catchment-planning/WaterBody/GB104028057820).

This waterbody is classified as being Moderate Ecological Status under the most recent (2016) WFD assessments. That classification is primarily due to a rating of "moderate" for zinc pollution, whereas biological elements are reported to be "high" or "good" status. This waterbody is not classified as "heavily modified" which is somewhat surprising given the extensive channel realignment and frequent presence of weirs and associated impoundments that served a multitude of mill/waterwheel structures along its length – particularly within the surveyed reach.

This report refers to a reach between an upstream limit at SK 16006 72973 and a downstream limit at SK 17075 72908. The parallel arrangement of Mill Leat and main river channel mean that it is not possible to list observations in a strictly linear sequence from upstream to downstream (or vice versa). Consequently, named features have been added to a sketch map to aid interpretation of findings (Fig. 1).

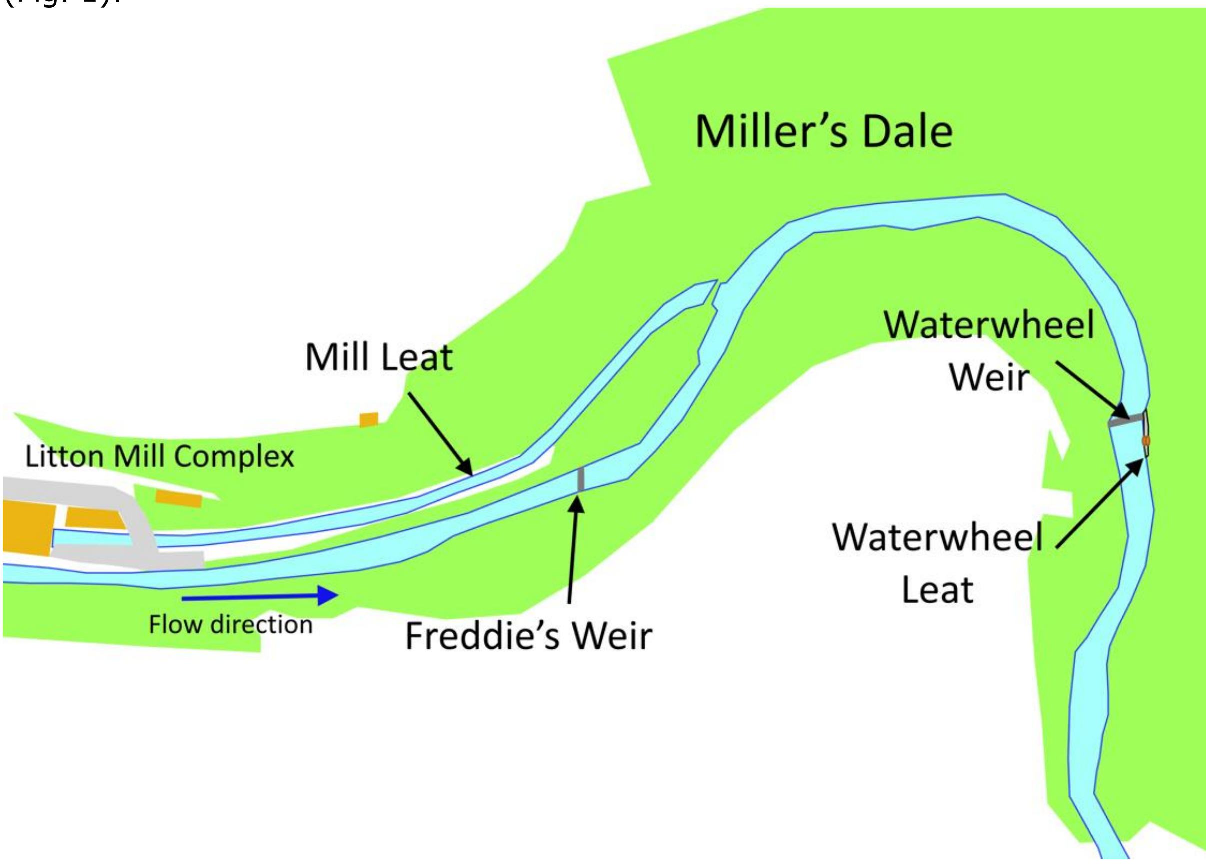

Figure 1: Sketch map of main surveyed features

The principle aims of this visit fall under two main themes. Firstly, to determine how best to manage and improve habitat associated with the Mill Leat at Litton Mill. Secondly, to identify opportunities to improve habitat within the surveyed reach of the main River Wye.

Throughout the report, normal convention is followed with respect to bank identification i.e. banks are designated Left Bank (LB) or Right Bank (RB) whilst looking downstream.

2. Habitat Assessment

At the upstream limit of this visit the main River Wye is diverted by a sluice through the Litton Mill complex. This feeds an old Mill "leat" (side-channel) which forms a small, wooded valley with a footpath/causeway on its RB and a steep wooded slope along its LB. The footpath/causeway forms the LB of the main river below Litton Mill until the leat rejoins the main river beneath a small, wooden footbridge (visible on the sketch map, Fig. 1 and pictured in Fig. 2).

Figure 2: Footbridge over mill leat where it joins the main river (photographed from centre of main river channel looking up along the course of the leat).

Although the valley side that forms the LB of the leat is very steep, the longitudinal gradient of the leat is very low. The width of the leat channel has, presumably, been designed to accommodate considerable flows that would have been necessary to the historic operation of the Mill structures. Consequently, the low gradient channel is also wide relative to the amount of flow normally experienced in the artificial channel. Two ways to slow a river down are to increase the cross-sectional area and to reduce the longitudinal bed-slope. Therefore, physical conditions within the leat mean that its substrate is dominated by fine particles since the flow is generally very slow for the majority of the time, allowing fine material to settle on the bed.

A relaxed attitude to management of woody material in the leat means that some effective backwater refuge habitat has developed (e.g. Fig. 3); however, reinstatement (if it were possible) of a more natural flow regime and gradient would greatly benefit the ecology of the reach, including invertebrate and fish populations.

Figure 3: Typical conditions within the mill leat. The bed is dominated by soft muds and sand – so has little value as a spawning resource or habitat for many of the invertebrates of primary benefit to angling. However, the complex cover formed by fallen trunks and capacity to act as a slowed-flow backwater during spates do provide a useful function as refuge for juvenile and adult fish.

The bed does have a considerable depth of soft mud/sand before firmer substrate is reached. Given the industrial heritage of this area, it is possible that more recent relatively "clean" sediment deposits are capping over more contaminated material. However, the total amount of fine sediment – whether clean or contaminated – is small compared to the huge deposits within the reaches impounded by Cressbrook weir (1.6 km or so downstream). The impounded lagoon formed by Cressbrook weir is approximately 700 m long and up to 50 m wide. Consequently, the risk posed by remobilisation of any sediment within the leat is likely to be negligible.

As part of this visit, the WTT were asked to comment on the potential viability of improving spawning conditions within the leat – since it represents over 300 m linear reach of potential new habitat. While it would be possible to "seed" this area with gravel, the major challenge is the lack of gradient and the overall propensity for fine sediments to accumulate. As a result, a change in the ratio of flow split or dimensions/gradient of the channel between the main channel and the leat would be required to generate sufficient flow to support spawning activity (and to have a chance of maintaining silt-free gravels). Therefore, any increase in flow down the leat comes at the cost of reducing the flow down the section of main-river running parallel to the leat.

Overall, it seems that the most direct route to improving spawning success would be to concentrate on the conditions within the main river channel. At the same time, the management of the riparian (waterside) habitat surrounding the leat could enhance its "backwater refuge" value. That compromise is likely to maximise the relative strengths of existing habitats.

Currently, the dense tree canopy has almost blanket coverage over the leat. Particularly during the warmer months of the year when trees are in full foliage, the artificial channel will be almost completely shaded throughout its full length. The canopy cover (even in autumn) and soft silt bed can be seen in Fig. 4.

Figure 4: Canopy cover throughout the length of the leat upstream of the confluence with the main river. Note also the fine bed material that is at least two feet deep (and possibly more) in many places.

Although some areas of complete shade are a benefit in hot summer conditions, there is also merit in creating both dappled light as well as scattered openings in the canopy. This will promote a more interesting growth of understory species – augmented by the good work carried out by the fishing club to control the invasive Himalayan Balsam. In the absence of such control, the native understory species would be unable to compete and flourish against the rapid growth of balsam. A dual benefit of more varied light/shade regime and also in-stream cover would result from hinging saplings and larger trees (cabling to their stumps if necessary) into the margins of the leat.

The localised increase in available light would promote some passive narrowing of the channel via ingress of understory vegetation. At the same time, the creation of additional marginal "brashy" cover at scattered locations would actively narrow the channel at those points and generate some diversity in flow depth and velocity.

In addition to canopy management directly adjacent to the stream, a similar scattered and "light touch" approach to rotational coppicing of the woodland on the steep LB is recommended. The timber and brash arising from such activities could be utilised both to create terrestrial habitat such as log piles within the woodland – but also potentially used to enhance aquatic habitats as well.

Coppicing a very small proportion (perhaps between 2 and 10 percent) of the trees every one to two years would create more diversity in the age/height/percentage cover of the woodland canopy. This periodic thinning, combined with the coppice regrowth is a simple way to stagger the heights of trees within the woodland. For flora and fauna, structural diversity in the habitat is what creates additional opportunities for biological diversity to thrive. For context, the steep LB and the footpath/causeway on the RB of the leat can be seen in Fig. 5.

Figure 5: Facing upstream the causeway (RB) is to the left of the frame while the steep, wooded slope (LB) is on the right of the frame.

Surveys and advice on bat habitat associated with veteran trees will be important to ensure that there are no unacceptable impacts on protected species. Similarly, it is important to leave standing dead-wood habitat where that can safely exist (this is vital for a number of rare invertebrate species – particularly beetles).

Turning to the main river reaches that were surveyed for this report, a number of interesting conditions were noted. As mentioned in the introduction, although not identified as a "Heavily Modified Waterbody", the history of mineral mining, milling, associated processing and transport has modified the river channel extensively. Measures have been taken to reinforce the "toe" of the banks (the bottom of the bank where it joins the riverbed) with both stone and also a single line of planted trees. The roots of those trees, combined with stone-work, act to produce a strong matrix that resists erosion (e.g. Fig. 6).

Of course, the formal mill-pools and associated weirs and retaining walls are much more obvious examples of this channel modification and realignment, but the long, sweeping bends and straight glides in the "greener" sections are just as carefully engineered. The sequence of small and large weirs (e.g. Fig. 7) throughout the valley are all highly significant in limiting the capacity of the river to create high quality habitat.

Figure 6: Blocks of limestone and single line of trees planted on RB (left of frame) to consolidate straightened channel, plus "Freddie's weir" that acts to reduce the erosive forces acting on the banks.

Figure 7: Facing downstream from the crest of Freddie's weir, single line of trees and stonework on RB also visible.

The combination of impoundments and bank reinforcement substantially reduce both the input and subsequent transport of gravels to areas where they can form spawning beds. In the absence of artificially reinforced banks and weirs, the natural wandering of a river within its floodplain over time causes gravel to wash into the system. Banks erode on the one hand, and then the material that washes into the river forms a deposit to offset that erosion. For instance, gravel inputs will settle in new features downstream such as point bars (the "beaches" that form the inside of river bends), riffles and mid-channel bars.

Of course, where intensive land-use results in very shallow or no root horizons (creating weak banks) and flashy runoff (creating high erosion rates), that erosive process can run rampant until a new equilibrium is re-established. However, it is important to realise that essentially halting erosion will choke off the supply of vital spawning substrate and is equally unnatural and disadvantageous.

Doubling down on that reduced sediment input due to engineered banks, installing weirs impounds water and traps gravels and prevents them from being redistributed. In other words, the conveyer belt that takes gravel from the banks and moves it to the points at which it can temporarily accumulate (and be useful for spawning) is cut off.

The continual, gradual "turnover" of gravel as it slowly shuffles downstream is essential for forming loose mounds of gravel that provide suitable spawning substrate and ensure good egg survival. This is because it helps to preserve silt-free gaps between the irregular and ill-fitting chunks of gravel. Trapping gravels in one spot (behind weirs) will create a giant filter-bed that, over time, has its pores clogged with fine material. At that point, the ability for oxygenated water to pass through those pores in the mounds of gravel is removed. This makes for very poor survival of eggs of gravel-spawning species like trout – since they require continual irrigation with oxygen-rich water. By that point, much of the habitat for beneficial invertebrate species has also been degraded or even lost. This may be one of the reasons that sections of the River Wye in less impounded, but otherwise comparable, reaches often score more highly in invertebrate surveys. To that end, cross-checking with scores from free-flowing sections (that also have a more continuous supply of bed-material – see comments pertaining to the riverbed directly downstream of Freddie's weir) could be an instructive exercise.

In common with other "base-rich" (limestone and chalk) rivers and those with high quality juvenile habitat, poor egg survival can be offset somewhat by the survival and growth-rate of offspring that do survive. The richness of the environment has the potential to make up for at least some of that deficit. However, in artificially degraded environments produced by impoundments, the efficiency of avian predators is increased greatly. Those pressures are more intense in cold winters when stillwaters freeze over (and rivers may remain ice-free). Banking on increased survival of a reduced number of offspring is, consequently, a risky strategy.

There is evidence of the impacts of reduced gravel input and transport when the bed of the river is examined within the surveyed reaches. For instance, Fig. 8 shows the bed **below** (downstream of) Freddie's weir to be predominantly large cobbles and limestone blocks, interspersed with sandy substrate that has filled the gaps between the rocks. Sand is, of course, more easily washed over the weir during a spate than the gravel which may become trapped on the upstream side of the barrier, starving areas downstream. At the same time, the high flows that can move gravel will export those chunks and pebbles from below the weir (to be replaced by the incoming sand and silt that drops out of suspension as the flows return to normal/low conditions).

That process will tend to leave the gravels and other material on the upstream side of the weir where it will deposit in a more aggregated (or "unsorted") mass, with the other major unintended consequence of shallowing the pool upstream. This was photographed in Fig. 9 when standing on the upstream side of Freddie's weir.

Figure 8: Chunks of (often algae-covered) limestone that are locked into the bed and interspersed with sand. The "gravel" particle-size fraction is notably under-represented.

Figure 9: Behind the lip of the weir on the upstream side, there is a "cake-mix" aggregate of cobble, gravel and sand. The "unsorted" nature of this deposit means that inter-gravel pores are clogged and it is not viable spawning habitat.

As well as blocking the transport of (already reduced inputs of) gravel, the weir structures also artificially redistribute flow across the channel, with each weir effectively resetting the process. This creates homogenous habitat (e.g. Fig. 10) since there is little diversity in flow velocity across the full cross-section – and hence little variety in associated deposition/erosion of bed material – which is vital to produce a diverse, healthy bed profile of pools and riffles. The greatly simplified and dissipated flows lead also to increased siltation and smothering of the bed with finer sediment throughout the impounded reaches during low flows.

Figure 10: Impounded section above Freddie's weir with little variability in bed profile and reduced opportunity for fish to hide from avian predators.

The most significant impacts of the multiple weirs on the Wye probably derive from limiting the ability of the river to generate high quality habitat. However, there is also a more obvious (and potentially significant) effect on fish movement. In this regard, even surprisingly low barriers can have a marked impact on habitat utilisation for all fish life stages. For a fish to leap a barrier, it needs sufficient depth (generally regarded as three times the obstruction height) in the pool below to generate enough vertical swimming speed to make the leap. This is not always present. When you can see aquatic organisms like trout and salmon leaping at obstructions, it is an indication of an issue – particularly when the risk of injury is accounted for.

Additionally, wherever "white water" is visible flowing over a barrier (i.e. Figs. 8 and 11) – this indicates a large amount of entrained air within the flow. The physics of a fish swimming through water are radically impacted when air is entrained in the water – since the density and viscosity are vastly reduced. In short, fish's fins, tails and bodies don't swim very well in air. Even without lots of entrained air/white water, the flows may be so fast and shallow over the surface of a barrier that it exceeds the maximum swimming speed of migrating fish. Remember, juvenile fish also need to migrate/disperse.

Of course, if a fish tackles several barriers in sequence in order to move from their adult habitat to a suitable spawning site, it may injure or exhaust itself and reduce or prevent spawning success; but barriers also prevent juvenile fish from moving to find new territories and accommodate their ever-changing habitat requirements. Taken together, the reduction in ability of all fish to move between different types of habitat throughout their lifecycle puts them at greater risk and limits the potential of those fish populations.

Even when fish are able to find (possibly sub-optimal) breeding habitat between barriers to migration, there are other, more subtle risks. One of the challenges to animals that "home" to their own natal spawning grounds is how to avoid inbreeding. In response, trout (and other species) are able to use olfactory and visual clues that, on average, help them to breed with individuals that are not too closely related to themselves – and that have traits that are valuable to resultant offspring.

In order for this to work well, there needs to be a sufficiently large and diverse pool of potential breeding partners available. In fact, in the presence of poorly passable barriers, the total pool of potential mates (known as the effective breeding population size) can become dangerously small. The smaller the number of potential mates, the greater the likelihood of large, purely random shifts in the genetic makeup of offspring happening in one particular breeding season. This basically makes it more likely for "non-adaptive" (often detrimental) changes in the gene pool to occur. Unsurprisingly, big, random jumps in the composition of a gene pool are associated with an increased risk of extinction.

Without delving too deeply into population genetics, the issue of random changes within a population can be explained with a simple example. Imagine you have a bag of 5 red and 5 white marbles and wish to work out what the true ratio of red:white marbles; however, you are only allowed to reach in and take three marbles before making your guess. With such a small "population" you could very easily draw out three marbles of the same colour (and therefore guess that all 10 marbles were that colour too). In fact, it would be impossible for you to draw out the true ratio - that would need you to draw out 1.5 red and 1.5 white marbles (or half of each colour).
Now, imagine that instead of 10 marbles, you had 1000 marbles - half red and half white - and you were allowed to draw out 300 (i.e. the same proportion as 3 out of every 10). You'd then be very likely to draw out around 150 of each colour. That would make your guess of the true ratio far more accurate. The larger population size reduced the influence of pure chance.

The bottom line is, the smaller your "population", the bigger the role pure chance will play and larger and more frequent deviations from the underlying true pattern will happen. This is important if those large changes are in the natural gene combinations that make fish well adapted to their local environment.

Bringing it back to the Wye - it could be quite feasible to double the effective breeding population size by tackling the middle barrier of any series of three. The benefit to doing this is hard to appreciate without doing the "funny maths" example. Fish might well breed perfectly successfully for many generations, all the while hiding the fact that they were at an increased risk of future extinction through a chance shift in population genetics.

By increasing effective breeding population size, you might have no tangible effects on the fish that are produced (since you won't have a comparison case). What you will do is improve the future chances for members of those populations to remain resilient and well-adapted. Of course, increasing the potential for "gene flow" between a steadily larger pool of individuals by tackling more barriers will compound that benefit.

Taken together, it is easy to see that there is no comparison between the far-reaching benefits of removing weirs and minimal benefits of fitting a fish pass or easement. The vital downstream conveyor belt of spawning gravel is not reconnected when the barrier remains in place over the full width of the river. Additionally, the impounded/silt-accumulating flows upstream of weirs are unable to create localised bed-scour associated with good spawning gravels (e.g. Fig. 12). The often ridiculous cost discrepancy between fish passage options and simple weir removal should not be overlooked, with removals usually being an order of magnitude cheaper.

Figure 11: Waterwheel weir (marked on map in Figure.1) – a complete barrier to fish under most flow conditions.

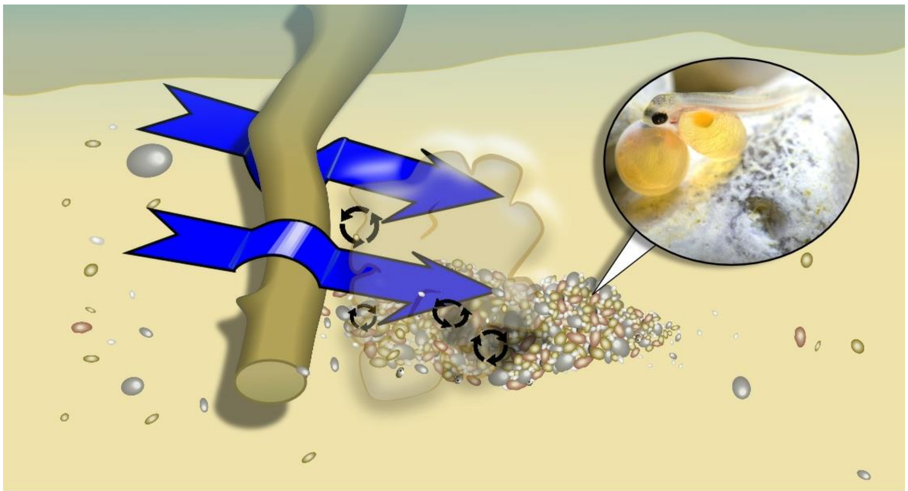

Figure 12: Flow is required under, over and around obstacles to create localised bed-scour which blows silt out from gravel deposits and produces mounds of loose gravel. The loose, silt-free particles can then protect trout eggs and developing juveniles (alevins) that hide in the gaps while being supplied with oxygenated water. Impounded reaches accumulate silt and cannot create the "gravel-cleaning" flows.

The preceding detail should help with the interpretation of the following observations made at the Waterwheel weir marked on Fig.1. The arrangement of the weir and a narrow stone leat which was used to drive a wheel can be seen in Figs. 13, 14 and 15.

Figure 13: Waterwheel weir - with the narrow leat on the LB (right of frame) obscured by vegetation.

Figure 14: Narrow leat supplied with head of water by the weir.

Figure 15: Continuation of leat via derelict waterwheel before disappearing into vegetation.

On the face of it, the leat may be viewed as an opportunity for modification into a baffled fish-passage structure. However, it is difficult to turn it into an effective solution because of a number of factors:

- The location of the downstream entrance would not be easy for fish to find
- The limited flow capacity would not produce very much "attraction flow" (which is also vital for fish to navigate past barriers).
- Fish passes/easements of this nature do not work well for fish trying to migrate downstream (whether juvenile or adults).
- The ability of fish to successfully swim up the leat is very difficult to maximise under a range of different flow levels and for a range of different sizes/ages of fish.
- The vegetated silt bank that currently obscures the downstream entrance would need continual management/periodic removal.

The other limitation with any such fish passage easement is that there is no benefit to habitat quality. The downstream section will still suffer a reduced gravel supply and the upstream section will remain impounded and uniform. Both conditions will reduce the opportunities for successful spawning, egg survival and dispersal/habitat utilisation to levels far below what could be achieved.

Removing the Waterwheel weir would increase the quality and amount of spawning habitat in the currently-impounded reach (and possibly downstream as well). Both improvements would be extremely valuable. This is an especially important opportunity given the numbers of trout that are restricted by additional weirs in areas up and downstream of the Waterwheel weir. For instance, the area upstream of Cressbrook Mill weir is essentially "lake" habitat (i.e. Fig. 16) with no spawning opportunities and likely to be of limited value to juvenile fish. Given that all trout (whether sea trout or not) migrate from their adult habitat to the habitat that is ideal for spawning – it is fair to say that there is no such thing as a non-migratory trout. By both improving the quality of existing spawning habitat and increasing its accessibility, there is a greater opportunity for the trout living within the river up and downstream of the current obstructions to contribute to a larger effective breeding population.

Figure 16: Impounded lagoon "Cressbrook Lake" photographed from the LB facing slightly up and across stream.

Furthermore, the best way to create deeper pool habitat is to have the river drive the bed down - for instance on the outside of bends or by localised scour induced by submerged woody material. In this way "self-cleaning" adult pool habitat is created – rather than holding water back to create depth which, inevitably, shallows through sediment deposition over time. The secondary advantage is that the material scoured from the bed will be deposited downstream where it can form excellent quality, silt-free spawning gravel.

Recommendation

Consequently, a list of priority actions to consider for the reaches examined in this report are:

- Remove sufficient sections of Freddie's weir and Waterwheel weir to reinstate the river's natural gradient, enable improved bed-material transport, reduce siltation and reinstate natural fish passage through the currently impounded reaches (it would be advisable to undertake this one weir at a time so that effects could be noted and attributed correctly). As well as other necessary permissions, it should be assumed that Peak District National Park Authority consent would be required: http://www.peakdistrict.gov.uk/planning.

- Securely install large woody material to aid sorting and maintenance of spawning gravels both upstream and downstream of the weirs (subject to consent/exemption by the Lead Local Flood Risk Authority: http://www.derbyshire.gov.uk/environment/flooding/ordinary_watercourse_consents/default.asp).
- Consider "seeding" the channel with locally-appropriate limestone gravels to mitigate the reduced supply due to extensive channel modifications (with the same consenting considerations as for large woody material installation)
- Undertake light, rotational coppice work (aim to preserve at least 60% of the riverside canopy cover): www.shropshirehillsaonb.co.uk/wp-content/uploads/2010/10/Management-of-Riverside-Trees-Feb-2013.pdf (Natural England should be consulted according to the conservation designations of the site – including that of the Wye Valley Site of Special Scientific Interest: https://www.gov.uk/guidance/protected-areas-sites-of-special-scientific-interest).
- Extend rotational coppicing to the woodland on the LB of the leat – pending suitably certified forestry workers and any bat habitat surveys that may be required.
- Use material arising from coppicing to:
    - Create log-pile habitat in the woodland: https://www.buglife.org.uk/activities-for-you/wildlife-gardening/create-your-own-dead-wood-habitats
    - Introduce securely-anchored woody material to the stream in the form of small tree "kickers": https://vimeo.com/72720550
    - Lay, wedge and securely anchor larger trunks/limbs across the channel in the open-canopy areas to create low shade and structural diversity, augmenting the naturally-occurring examples of this habitat
    - Hinge (in the manner of hedge-laying) saplings into the leat to produced scattered pockets of marginal brash habitat
    - Consider undertaking some supportive planting of marginal aquatic species in areas where canopy cover is reduced (e.g. sedge grasses and flag iris or other locally-appropriate species)
    - Produce logs to be pinned into the riverbed of the main river to aid gravel retention and sorting.
- Consider (subsequent to other higher-priority actions already listed) pursuing a project to increase the bed-slope within the Litton Mill leat by means of substrate introduction. For instance, if the feed of water into the leat is sufficiently high above the current bed of the leat, it may be possible to create a gravel and cobble channel with enough longitudinal slope to generate flow and produce a series of riffles and pools. For the best chance of success, this should be examined as a possibility when the influence of downstream impounding structures has been reduced.

Since the Wild Trout Trust does not have any regulatory function or responsibility, these recommendations are made purely according to our best current, available knowledge on how to promote healthy, self-sustaining fish and invertebrate populations. Further advice and clarification of any points raised in this report is always available by contacting our team of Conservation Officers. In addition to permissions and considerations highlighted in this report, there may well be additional requirements that need to be satisfied before work can be undertaken.

Although assistance from the Wild Trout Trust is in high demand, it may also be possible to provide support in setting up and helping to deliver the habitat work aspects of the above suggestions. Maintaining a dialogue with our Conservation Officers is the easiest way to progress with assisted practical work and training. A more detailed project proposal that outlines the size and position of potential in-stream structures would be produced once an overall plan of action is settled upon through discussions with the club and riparian ownership.

Acknowledgement

The WTT thanks the Environment Agency for supporting the advisory and practical visit programmes (through which a proportion of this work has been funded) in part through rod-licence funding. The WTT would also like to recognise the generous offers of support by the membership (both via legacy donations and current fund-raising activities) of Cressbrook & Litton Fly Fishers Club. Such funds may be possible to use to contribute towards future works arising from this report.

Disclaimer

This report is produced for guidance and not for specific advice; no liability or responsibility for any loss or damage can be accepted by the Wild Trout Trust as a result of any other person, company or organisation acting, or refraining from acting, upon guidance made in this report.