Water Framework Directive Ecological status failure for trout: investigation into potential causes and suggested remediation on waterbodies GB112069060780 (upper Etherow) and GB112069061050 (lower Etherow)

Problem definition

Advice in this report arises from the following:

- Initial site visit made by Paul Gaskell of the Wild Trout Trust (WTT) and discussions with Kevin Nash and Cathy Ellis of the Environment Agency (E.A.) on 29/03/2012
- The report "River Etherow and Glossop Brook, Assessment of Options for River Restoration" produced by James Holloway & Dr Di Hammond, The River Restoration Centre (RRC), Building 53, Cranfield University, Cranfield, Bedfordshire MK43 0AL
- E.A. fisheries data from four sampling points (Fig.1).
- A second site visit for targeted invertebrate sampling (3-minute kick sample) and further in-channel investigations by Paul Gaskell on 18/05/2012

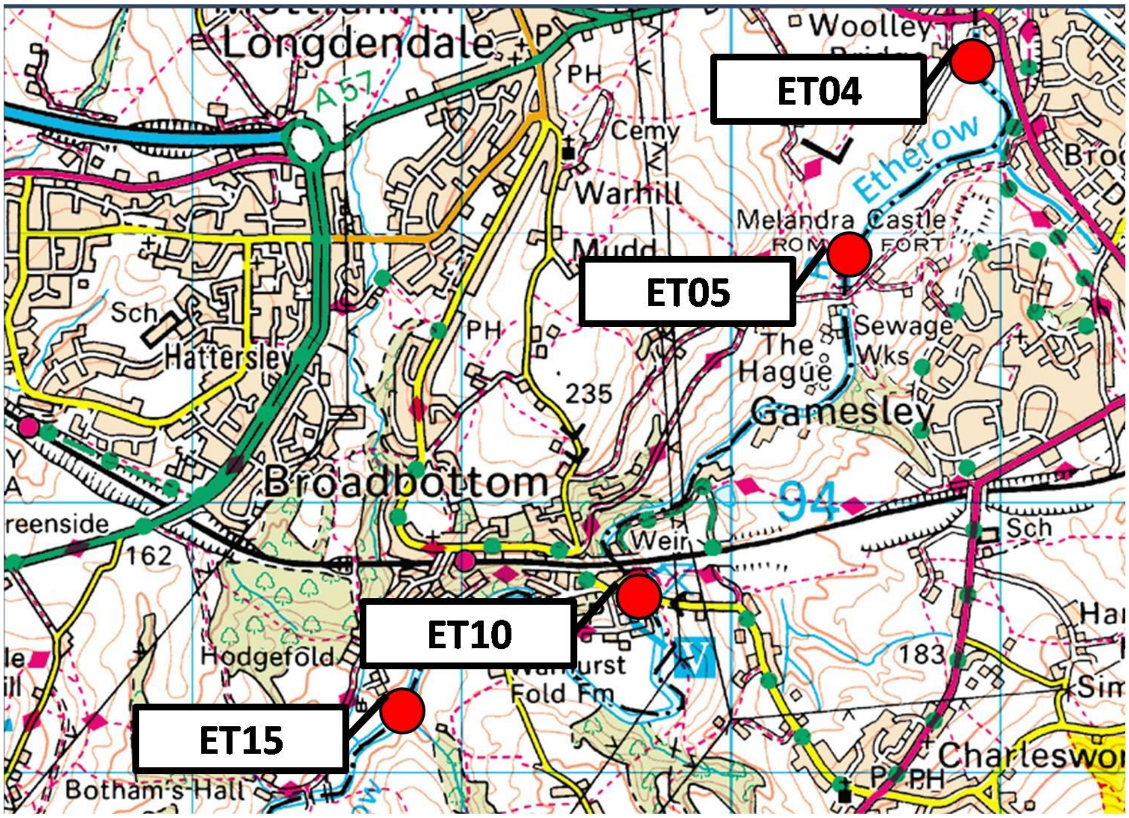


Figure 1: Locations and identity codes of E.A. fisheries monitoring sites referred to in this report. The upper limit of the lower Etherow WFD waterbody lies approximately half way between ET04 and ET05

Initial correspondence with E.A. personnel on the Etherow indicated that concerns had been raised over the apparent decline of trout populations noted during fisheries monitoring surveys. Examination of fisheries survey data indicate that, for one site in particular (ET04), an apparent decline has been noted from 2005 onwards (Fig. 2). Conversely – when taking the confidence intervals around population estimates into account - sites further down the river appear not to show a similar decline. Instead populations at ET05, ET10 and ET15 apparently exist at a generally lower density – at least over a time span covering the apparent decline at ET04 (Fig. 3).

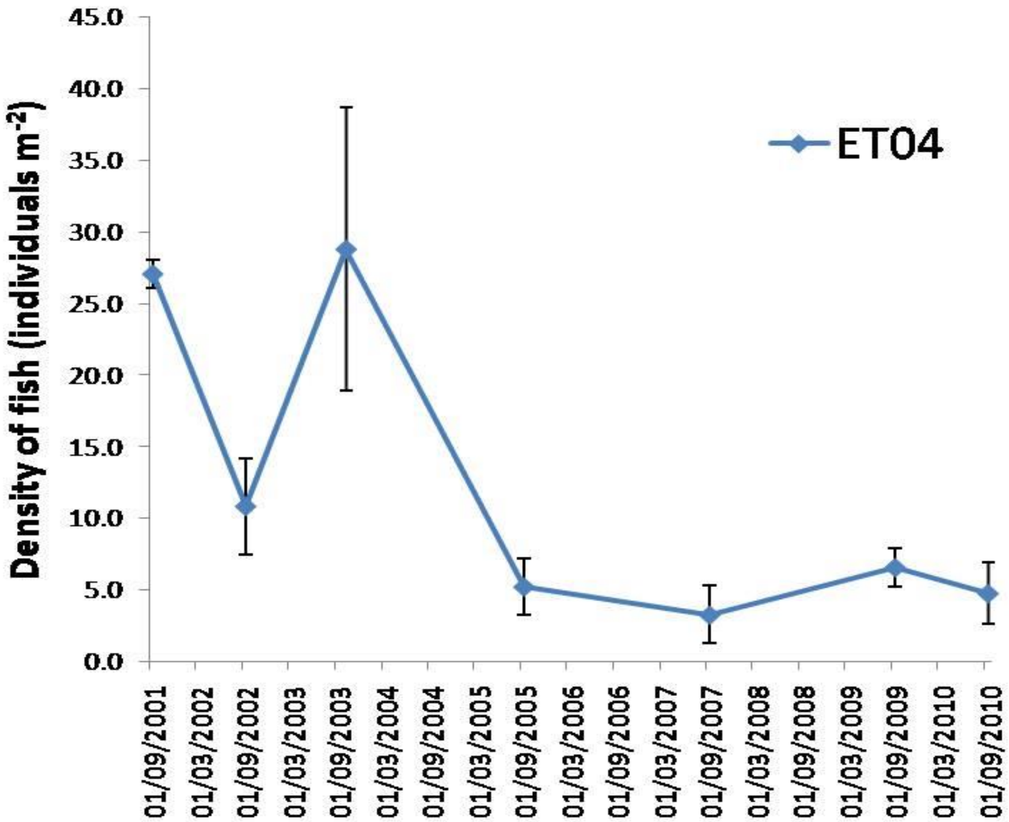


Figure 2: Density of trout per m^2 (± 95% Confidence Interval) at sampling location ET04 estimated using Carle & Strub Maximum Weighted Likelihood method during electric fishing surveys spanning the dates indicated

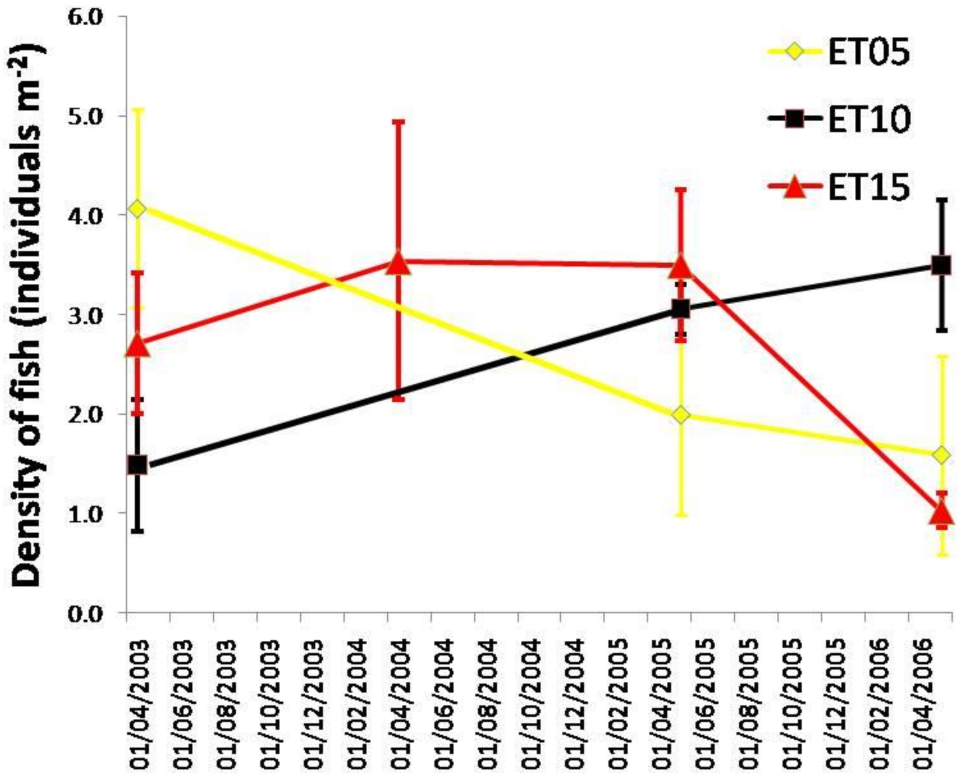
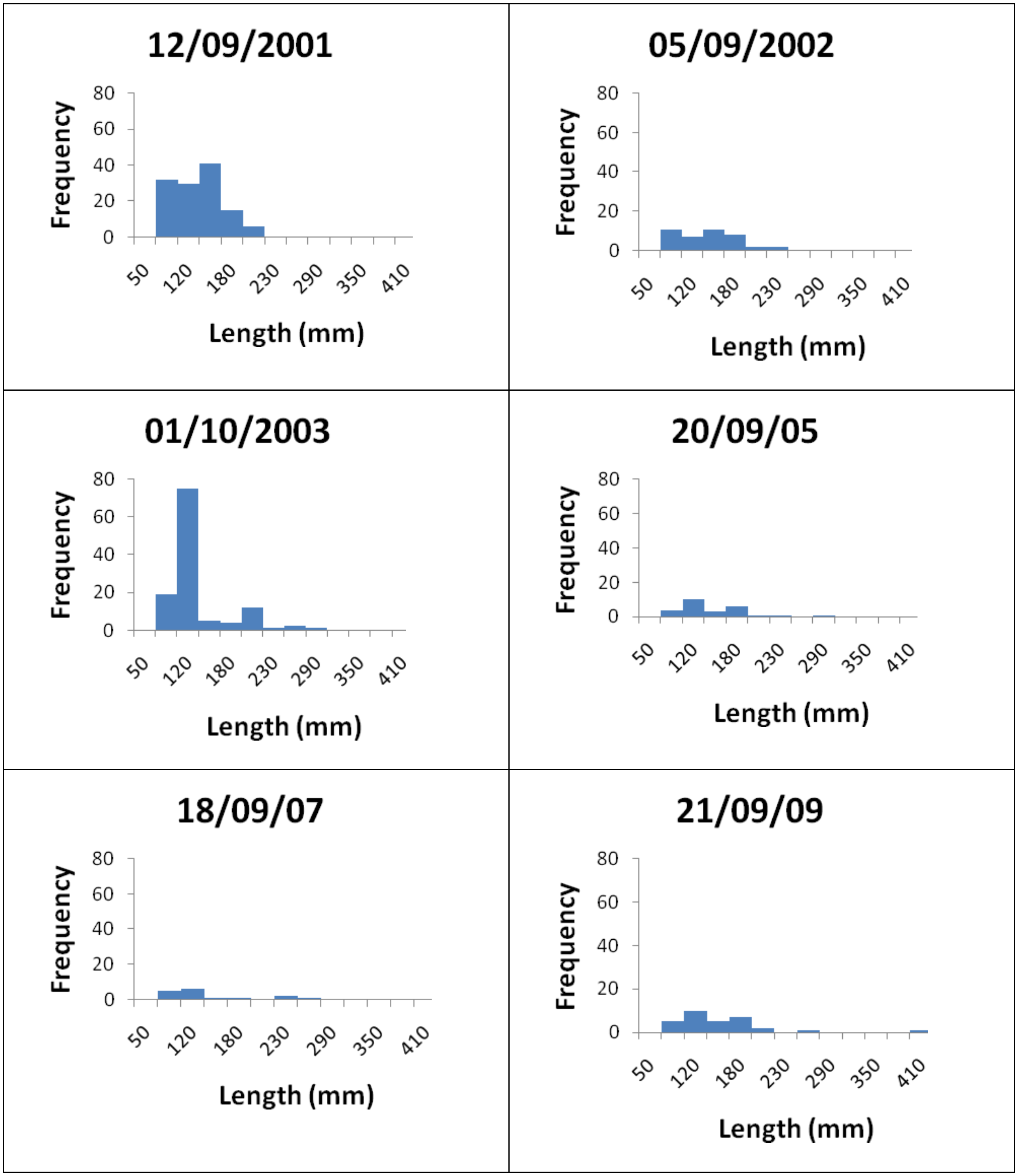


Figure 3: Density of trout per m^2 (± 95% Confidence Interval) at sampling locations ET05, ET10 and ET15 estimated using Carle & Strub Maximum Weighted Likelihood method during electric fishing surveys spanning the dates indicated. No generalized reduction in densities could be identified at these three sites over the time period for which data are available.

A more detailed examination of monitoring data collected at site ET04 indicates that high densities of trout previously recorded predominantly consisted of juvenile fish less than approximately 180 mm in length (Fig. 4). Trout, as with many fish species, naturally undergo high mortalities at juvenile stages. In locations such as ET04, where the depth and velocity of flow is suitable for juveniles, it is normally expected that juveniles will outnumber larger adult specimens by a considerable margin. Furthermore, even when surveys at ET04 report high overall trout densities, the presence of larger fish (e.g. > approximately 210 mm in length) is sporadic and only ever occurs in low numbers (Fig. 4). The decline in trout density that has triggered the concern over their population status on the upper Etherow should, therefore, be characterized as a reduction in juvenile numbers.

The generally lower densities of trout recorded at sites further downstream (indicated previously) may be a result of a prior decline that is not captured by available monitoring records. Based on the currently available information, it is not possible to discern whether – at least during the period since post-industrial water quality is likely to have improved – juvenile trout densities have previously been greater within those lower reaches.

Interestingly, even given the apparent reduction in juvenile densities at ET04 and similarly low densities at other sampling locations, the Etherow appears to support sufficient adult trout numbers to easily support a viable catch and release recreational angling amenity (Fig. 5). However, it is important to note that this does not automatically negate the need to investigate generating greater *resilience* of trout populations by improving the prospects of juvenile fish.



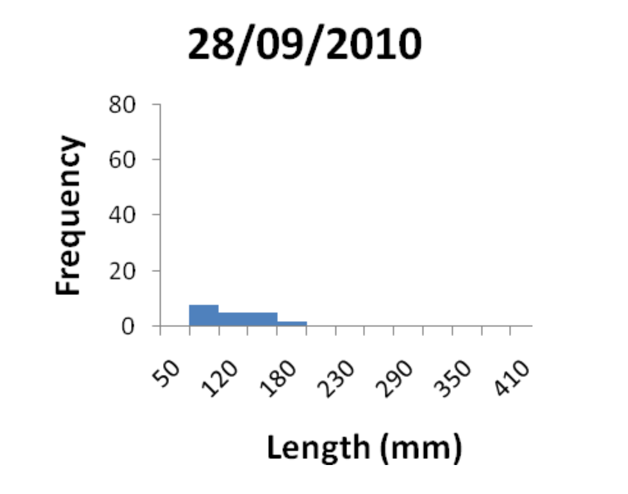


Figure 4: Frequency distributions of length (mm) of trout captured during autumn electric fishing surveys at ET04 between 2001 and 2010. The most striking feature is that reduced densities are predominantly a result of lower numbers of juvenile fish.

Figure 5: Two of a dozen wild trout caught on artificial fly and returned during approximately 90 minutes of angling on the Etherow

Approaches to identifying potential cause(s) of reduced trout density on the Etherow

This report seeks to identify gross impacts and factors that are clearly outside niche requirements of wild trout. The mitigation or removal of such gross factors is the most reliable means of improving the prospects for wild trout or other species of conservation interest. It must also be acknowledged that any gross impacts may, currently, be masking more subtle limiting factors. These masked factors would only become apparent after the most obvious problems are tackled. Conversely, in some instances, the solution offered to a particular impact may also simultaneously tackle other gross and subtle problems. Where possible, such “catch all” options should always be pursued for the multiple potential benefits that they offer. The main categories of issues considered during this investigation are presented on the following page (Table 1.)

Table 1: Categorised potential impacts

"Bottom up" effects	"Top down" effects	Fundamental impacts
Poor water quality reducing invertebrate foodweb productivity	Increased bird or fish predation	Direct mortality of fish via pollution (either aqueous or sediment-mediated)
Insufficient Primary productivity/nutrient retention in stream leading to lack of invertebrate foodweb productivity	Invasive crayfish predation of trout eggs	Insufficient connectivity between high quality habitat patches required be each stage of trout life cycle
	Over-exploitation of fish stocks via catch and kill angling or poor angling practices leading to fish mortality	Habitat degradation and habitat bottlenecks for key lifestages

The factors listed in the "bottom up" and "fundamental" categories would be likely to be considered during most initial attempts to understand waterbody impacts. The "Top down" category, in this case, consists of potential impacts inferred from discussions with E.A. staff (i.e. invasive crayfish predation of trout eggs), fishery survey monitoring data (i.e. declines of juvenile fish classes at ET04) and site visit evidence of angler's monofilament in tree branches (i.e. over-exploitation of fish populations/poor angling practices). Two separate visits to the river by WTT staff enabled investigations into habitat degradation, connectivity, water quality issues and stream productivity. Additional information on physical habitat and connectivity was derived from the "River Etherow and Glossop Brook, Assessment of Options for River Restoration" report produced by the River Restoration Centre.

Bottom up effects and aqueous/sediment-mediated pollution

On-site investigations at ET04 enabled the potential for gross water quality impacts to be ruled out as a cause for consistent fish declines at this site. The presence of abundant and diverse benthic macroinvertebrate fauna indicates a generally high baseline water quality and also a generally productive invertebrate foodweb (Fig. 6). Furthermore, the presence of a range of taxa especially sensitive to low oxygen levels (the three genera of Heptageniidae plus Nemourid stonefly larvae) shows that trout oxygen requirements are well catered for. The presence of several large (>12 mm long) *Gammarus sp*. individuals and large (>15 mm long) Trichopteran larvae also indicate that water quality has been acceptable to these organisms over the past several years. This indicates that serious episodic pollution has not impacted the system recently and that the baseline condition of "good water quality" is a reasonable to expect. Finally, the sensitivities to fine sediment inundation, metal pollution and pesticide residues accorded to the specific taxa identified in Figure 6 also indicate that direct impacts upon trout are unlikely to occur via any of these stressors. The lack of fine sediment impact on, in particular, *Baetis spp.* populations amongst gravel deposits in this reach indicates a good potential for post-spawning survival of trout eggs.

 *Heptagenia sulphurea*	 *Rhithrogena sp*.	 *Ecdyonurus sp*.
 *Baetis sp*.	 Nemourid stonefly	 *Hydropsyche sp*.
 *Gammarus sp*.	 *Asellus sp*.	**Figure 6: Invertebrate taxa sampled at ET04 on 18/05/2012 by PG that are intolerant of organic pollution/low Dissolved Oxygen (*Heptagenia*, *Rhitrogena*, *Ecdyonurus*, Nemouridae); metal toxicity and fine sediment innundation (*Baetis*); pesticide residues (*Gammarus*). The relative abundance (*Gammarus*>*Asellus*) could indicate a moderate amount of organic enrichment. Filamentous algae indicates some nutrient (N or P) enrichment.**

A degree of nutrient enrichment (presumably nitrogenous) may be indicated by the presence of some filamentous algae in the channel. Similarly, although greater numbers of *Gammarus sp*. were observed, the organic-enrichment tolerating *Asellus sp.* was also quite common. However, the nutrient enrichment does not appear to result in spikes in biochemical oxygen demand (BOD) during periods of algal die-back – as this would eradicate the previously noted taxa that are sensitive to low dissolved oxygen. Overall, therefore, the generally good water quality, highly productive and diverse macroinvertebrate community appear to be capable of supporting healthy populations of wild trout. Pollution and stream productivity are consequently rejected as primary causes of juvenile fish decline at ET04.

Top Down effects

Although some evidence of angling activity was noted (a short length of discarded fishing line of a heavy breaking strain), there is a much greater and far more obvious presence of anglers on many other comparable watercourses (e.g. south Yorkshire River Don). It may be of value for angler activity to be noted and recorded to confirm the impression of generally low exploitation throughout the Etherow system.

A potentially more likely explanation for reduced juvenile fish numbers at ET04 could be a change in natural predation pressure on fish. This could come about via:

1. Reduction in habitat features that provide cover from predation (with predator abundance relatively constant)
2. An increase in the exploitation of juvenile fish via immigration of greater numbers of predators, e.g. piscivorous birds, (with cover habitat remaining relatively constant)
3. Both reduced cover and increased predator abundance

In any or all of the above three cases, the measure that is likely to give the greatest benefit is the installation of submerged complex cover – for instance in the form of dense brash. It is commonly observed in a range of classical ecology experiments that increased physical habitat complexity reduces predator foraging success and, consequently, reduces prey exploitation. Studies on experimental pond systems and cormorants indicate this general effect also applies to prey fish populations targeted by cormorants. As an additional bonus, submerged brash cover also provides a significant cool water refuge during hot weather/low flow conditions. This can be vital to cold water species such as trout (and is an example of "catch all" multiple benefits arising from a single intervention). See "recommendations" for additional detail on installation of juvenile trout cover.

The final type of predation to be considered in the current report is that carried out by invasive, non-native crayfish on the eggs of trout. No evidence of crayfish was noted during either of the site visits (including that gathered during invertebrate kick sampling). However, their presence was indicated during discussions with local E.A. staff and 2005 was suggested as their earliest recorded appearance at site ET04. An investigation of the range and abundance of crayfish sightings may provide useful additional insight into the likelihood of associated negative impacts. Given the great difficulties in effectively reducing established crayfish populations - actions to negate such an impact would need to be radical. Part of the subsequently suggested habitat improvement works includes a strategy to survey invasive crayfish population size. Improved fish access and *extensive* and *prolonged* trapping of invasive crayfish in a constructed spawning and nursery area "haven" that occupies a manageable area with a naturally limited colonisation rate may provide a workable mitigation measure (See "Recommendations" section and also the existing example from the Lark in Suffolk - http://www.anglia.ac.uk/ruskin/en/home/faculties/fst/departments/lifesciences/staff/abby_stancliffe-vaughan.Maincontent.0005.file.tmp/Alien%20crayfish%20on%20the%20River%20Lark,%20Suffolk.pdf).

Habitat Degradation and Connectivity

The remainder of the impact identification process concentrates on observed habitat conditions. Surprisingly, if the presence of multiple weirs is ignored, the better quality habitat was witnessed in the historically-walled/industrially-modified sections of the river. The steep bedslope, when flows are not impounded behind weirs, has allowed the regeneration of valuable geomorphological variety - including point bars, lateral scour pools and a good variety of substrate particle sizes including gravels, cobble and boulders e.g. at National Grid Reference (NGR) SJ99679, 93690 (Fig.7). These factors are augmented by the presence of well-developed riparian woodland (although some Himalayan balsam was noted amongst the understory vegetation). The River Restoration Centre report also identifies a number of reaches displaying similarly varied and valuable habitat within modified/post-industrial reaches.

Figure 7: Point bar formation (right to upper centre of frame) with scour pool formed by "bank" resistance generated by wall footings (nearside) with varied mature woodland (picture taken prior to leaf-out) providing some lovely riffle and pool habitat for a variety of flow-loving species.

Unfortunately, not all modified sections of river have been able to regenerate so successfully. The most widespread cause of degradation that can be attributed to historic modification on the Etherow is the combined barrier and impoundment effect of the multiple weirs on the system.

Weir effects 1: Connectivity

The most obvious impact of impassable weirs is, of course, to limit free movement of species (such as trout) that migrate between different types of habitat during different stages of their lifecycle. Similarly, the ability to migrate away from pollution incidents is also a valuable facility. The improved resilience of populations that comes with increased opportunities to disperse between a larger variety of high quality habitat patches in order to physically complete lifecycles is a well known phenomenon. However, there are also other less obvious negative impacts imposed by constraints on dispersal. For example, the artificial barriers that prevent free movement and selection of breeding sites can result in reduced local adaptation by reducing gene flow between two or more sub-populations. With lower numbers of breeding individuals contributing to populations separated by barriers, a larger impact of purely random changes in gene frequencies can occur (via "genetic drift"). This is an example of a phenomenon known as the Wahlund effect and highlights that fish passage is not the sole preserve of species that migrate between freshwater and marine habitats. Moreover, it is important to recognize that (excluding natural bypass channel options) engineered fish passes which entail the weir being left intact do not operate equally effectively across all species and have a very stringent requirement for diligent maintenance. There is no fish pass that is as good as the condition of "no weir" – even when solely considering connectivity.

Weir effects 2: Habitat processes

The negative impact on habitat upstream as well as, potentially, downstream of weirs also lends weight to the notion that weir removal is the most desirable option in terms of wild trout and many other riverine species' conservation goals. The impoundment of water reduces both the average velocity and the variability of flow. Increased deposition of fine sediment occurs across the majority of the channel width and the variety of microhabitats is substantially reduced. The lack of opportunity for erosion and deposition to recreate valuable geomorphological variety is a natural corollary of a blanket increase in fine sediment deposition for example upstream of the weir at SK 01955 96855 (Fig 8).

Figure 8: Low crump weir at SK 01955 96855 that is impounding and degrading a section of habitat below the reservoir source of the river Etherow

The "trapping" of sediment behind weirs is also likely to impact on the transport of gravel and cobble substrate to downstream reaches (as well as limiting the value of such material upstream of the weir when it is buried in sand and silt). The headwaters that would previously have been a major source of gravel to the Etherow are, of course, lost to the reservoir system – another alteration to the sediment supply regime. In combination these effects mean that there is a potential for localized shortages of spawning substrate – particularly in the uppermost reaches. Ironically, some of this impact may be offset in reaches further downstream (although often to damaging excess) by a rate of bank erosion that is too rapid for optimizing biodiversity. For the purposes of moving this modified waterbody towards good ecological potential, it is important to identify priority structures that will enable the greatest value in improved connectivity and the greatest value to potential habitat quality improvement. See the "Recommendations" section of this report for further detail. The most obvious degradations of walled channelization and weirs (i.e. where there are few opportunities for varied geomorphology to develop between weirs) is evident between the source of the river below the reservoirs at NGRs SK 01955 96855 and SK 00895 95860. This latter grid reference is just above sampling location ET04, where good geomorphology and valuable riparian vegetation is - in contrast - evident.

Habitat impacts in rural reaches

Some of the worst overall impacts were noted in rural reaches of the Etherow. A combination of overgrazing and ad-hoc gravel extraction/flood bund construction have destroyed what ought to be a pristine river corridor.

Figure 9: Grazing, lack of tree succession gravel extraction at NGR SJ 99733 93398

The lack of varied riparian vegetation, and in particular the lack of regeneration and succession of bankside trees is significantly reducing the habitat value of this reach for a multitude of aquatic and terrestrial species. It is also contributing to the rate of erosion and flashiness of the river at this point that the landowners are apparently attempting to ameliorate by gravel extraction and construction of flood bunds. It would be far more effective to utilize in-stream brash revetments and exclusion of grazing and mowing to allow the formation of a soft, shaggy marginal flora. Supplemental tree planting would further consolidate bank resistance. Over and above the tackling of landowner-perceived erosion problems, these options would also confer significant biodiversity benefits – including improving the prospects for juvenile and adult trout.

Figure 10: Gravel extraction and ad-hoc bank regrading – presumably for attempted flood prevention at NGR SJ 99733 93398

Figure 11: Ad-hoc flood bund constructed from material extracted from the river bed at NGR SJ 99733 93398

Figure 12: Turf cultivation and lack of riparian tree regeneration/succession at NGR SJ 99765 93312

Figure 13: Lack of tree succession, showing incised channel and lack of buffer strip to attenuate runoff from surrounding cultivated and grazed land at NGR SJ 99765 93312. Compare the uniform flow and depth to the "post industrial" modified setting - but much higher habitat value - of Figure 7

Although the presence of a well-wooded bank improves matters just downstream of the turf cultivating operation, the opposite bank has been badly degraded by the presence of Japanese knotweed and Himalayan balsam (Fig. 14). This has resulted in a generally overwide/overshallow channel, but is also elevating the inputs of fine sand and silt above a rate that is helpful for good trout spawning success.

Figure 14: NGR SJ99580 93243. Good in-channel cover and increased bank erosion resistance on the left hand bank (left of frame) - but significant impacts of Japanese knotweed and Himalayan balsam infestation on the right bank (centre and right of frame). The bare sand left following annual die-back of these competetively dominant plants will wash into the river in great quantities during winter spates. This will also act to maintain a shallow and uniform channel – even though the opposite bank has improved resistance to erosion compared to the overgrazed and cultivated section upstream.

Recommendations

In the first instance, it is recommended that interventions to improve prospects for wild trout concentrate on two principle approaches:

1. Bringing degraded rural river corridor back into favourable condition
2. Strategic reduction of potential top down pressures at and above ET04 with improved connectivity and spawning habitat restoration at the head of the system

Measures to improve impacted rural reaches (e.g. NGR SJ 99733 93398 to SJ99580 93243)

Within the cultivated and grazed sections, the simple installation of buffer strip fencing, augmented by tree planting will be a huge step towards improving ecological status. The fencing should be sited at least two meters into the field side of the obvious bank-top and should also include gated access for either heavy plant or periodic light, managed grazing. In addition, to speed the natural narrowing and increased bank erosion resistance (as well as to provide excellent juvenile and adult trout cover); brash revetments should be installed at the bank-toe within this section (Fig.15).

Figure 15: Brash revetment and buffer strip fencing on installation (left) and four months post-installation (right)

Stem injection of Japanese knotweed and either strimming (below first node) or hand pulling of Himalayan balsam (composted on site) just prior to seed setting would give immediate benefits to the infested areas at NGR SJ99580 93243. Even in areas where upstream recolonisation sources remain, the WTT has seen (via Trout in the Town volunteer work) significant floral recovery in localized areas that Himalayan balsam is regularly "weeded" out. Similarly, because of the relatively slow initial establishment of Japanese knotweed, significant benefits to removal via stem injection exist. This option avoids any requirement for disposal of biohazardous waste on site as well as avoiding:

- Cutting and subsequently allowing fresh regrowth prior to spray treatment (and controlled disposal of material arising)
- Retreatment over 5 to 6 years
- Overspray onto watercourse with attendant toxicological impacts on aquatic environment

Integrated major works strategy to mitigate ad-hoc flood bund construction

An opportunity to integrate improvements to the rural site and those proposed subsequently for the upper, heavily modified, reach also exists. With respect to the rural reach – the removal of the flood bund could be offset (in flood risk terms) by the creation of a wetland/scrape area with improved connection to the main river channel on the opposite bank (Fig. 16). The gravel material arising from flood bund removal, connecting channel and wetland scrape creation could be transported for use in the improvements to the heavily modified channel upstream.

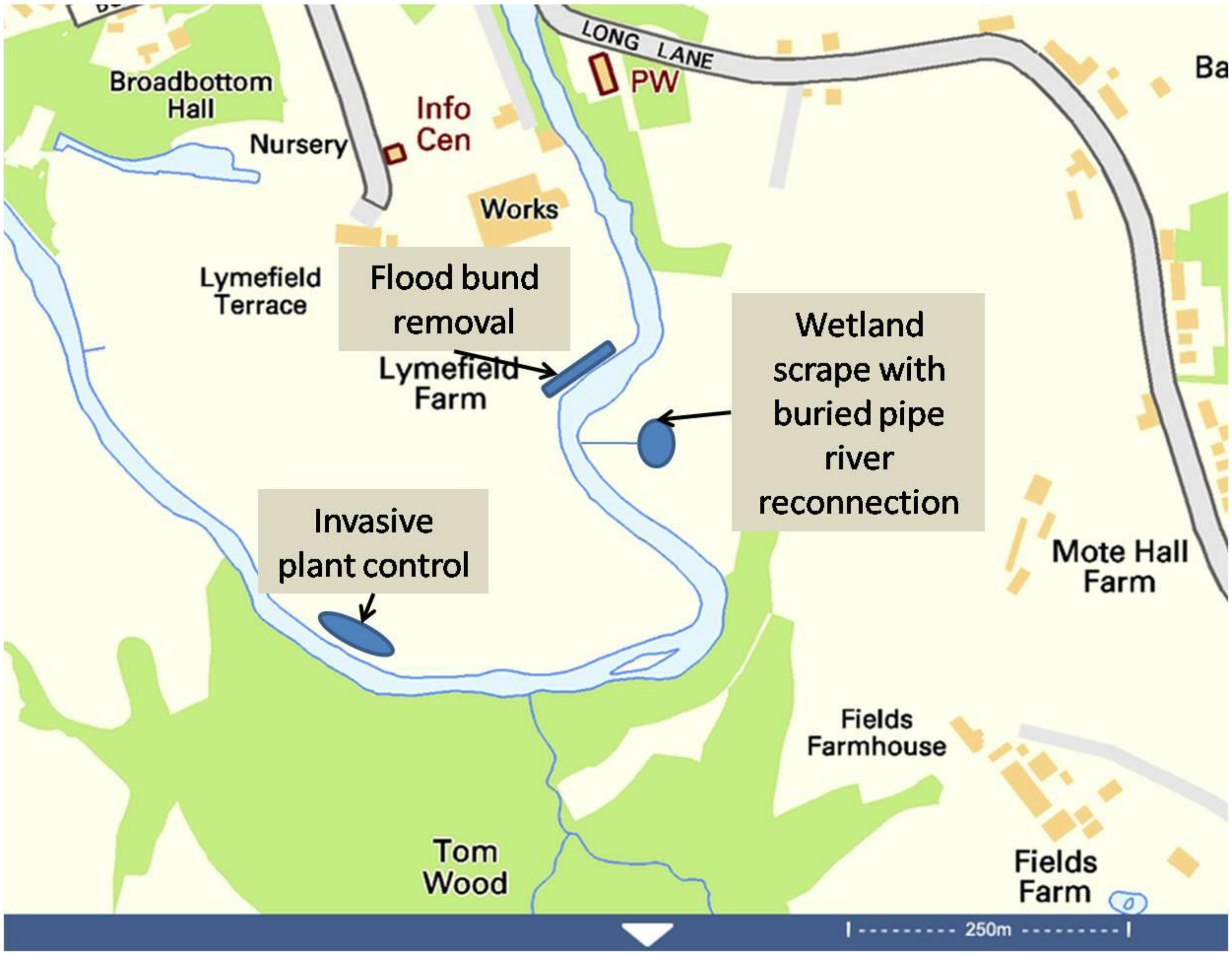


Figure 16: Major works to remove flood bund and offset flood risk by connecting wetland scrape to river channel (riverside outlet to pipe sited just above summer low flow level). Grazing exclusion from riparian buffer strip instated throughout with brash revetments in currently unfenced areas. Fencing and brash would negate need for existing “hard engineered” erosion control efforts

Grading and washing of gravels extracted during flood bund removal, pipe ditch excavation and wetland scrape creation to be used as part of an integrated solution to heavily modified areas upstream.

Fish and egg predation control measures, connectivity and recruitment haven creation

Direct fish predation reduction

In the channel at ET04 and directly upstream in the modified reaches, use of marginal brash will be an invaluable addition to habitat complexity (Figs. 17 and 18). This will function both to reduce predator exploitation of fish, but also as a cool water refuge for both trout and invertebrates with a lower maximal temperature tolerance. In the area of ET04 itself, there would be value in the inclusion of pinned log flow deflectors to promote localized bed scour and sorting of clean spawning gravels.

Figure 17: Typical channel and substrate in the area of ET04 - a great opportunity to increase juvenile fish survival by increasing wetted marginal brash cover

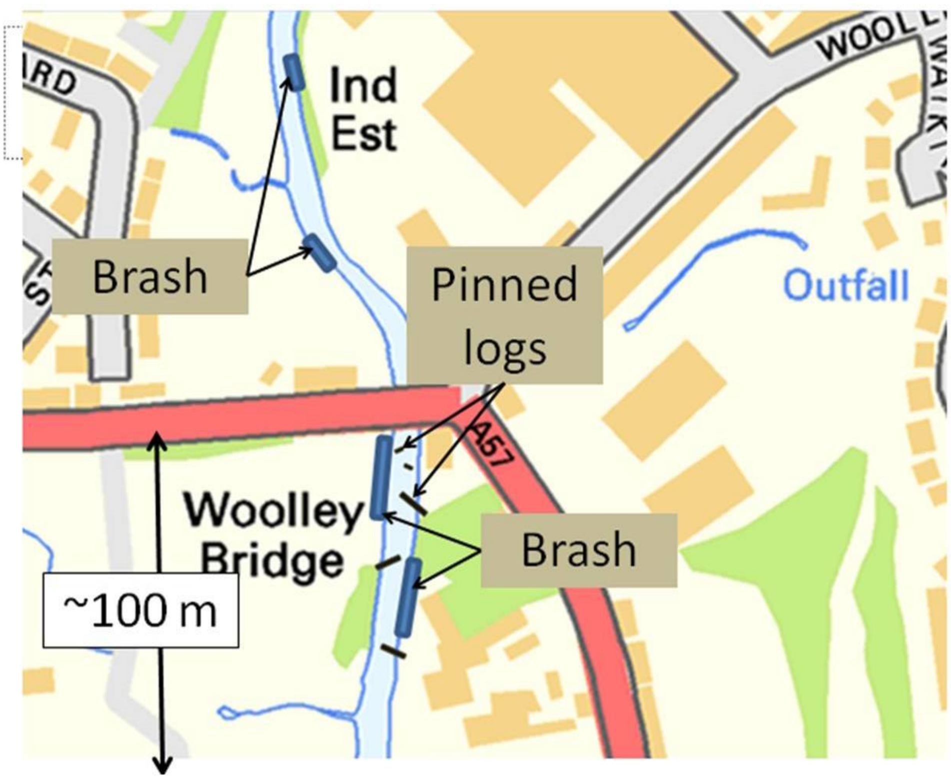


Figure 18: In-channel improvements at ET04

Egg predation reduction and recruitment haven creation

The uppermost reaches of the Etherow below the reservoir outlet potentially offer a dramatic improvement opportunity – not least because the currently poor habitat offers huge scope for improvement . The potential to create a hotspot for trout recruitment is based on several characteristics:

- The engineered banks may be more resistant to invasive crayfish burrowing
- The area is *potentially* small enough to trap crayfish with sufficient rigour to remove all breeding individuals
- The access to the upper reaches via the weir at SK01359632 (Etherow works weir) could potentially be heavily trapped to prevent crayfish re-colonisation from downstream

By taking different approaches to tacking connectivity at SK01359632 (Etherow works weir) and SK01959685 (Bridge and Waterside cotton mills weir); both Fig. 19, an optimal combination of fish access, habitat quality and prevention of crayfish re-colonisation is sought.

Figure 19: Locations of two key barriers (weirs) that, when tackled, could offer huge potential benefits to trout recruitment; Etherow works weir (red circle) and Bridge and Waterside Cotton Mills weir (yellow triangle)

A simple and cheap option for weir passage is suggested for Etherow works weir (Fig. 20) – and involves the use of a diagonal "baulk" on the downstream face of the crump weir (Fig. 21). This option provides access for trout, but still retains a potential "gatekeeping" function for invasive crayfish – as long as an especially heavy density of traps were to be sited around and within the easement. It must be acknowledged that crayfish can easily climb over (and live within) weirs that are totally impassable to fish. Consequently, there is no risk of increasing access for invasive crayfish over and above that which exists already.

Figure 20: Etherow Works weir panorama taken from River Restoration Centre report

Figure 21: Diagonal baulk bolted to crump weir (in this case constructed from wooden sleepers). Alternatives include concrete over rebar frame construction.

A small notch at the weir lip (i.e. the exit of the easement) would be beneficial to fish passage and also offer a small increase to the flow velocity and associated diversity upstream of the weir. However, a much more extensive increase to flow velocity and diversity would be proposed at the Bridge and

Waterside Cotton Works weir – via the breaking up of the weir structure. The arising material could be raked downstream in order to produce boulder-strewn “pocket water” habitat. The improvement potential offered by the increased flow energy is suggested to be consolidated via the introduction of gravels won from the rural restoration activities described earlier in the report. An appropriate rate of gravel retention and transport would be promoted by the introduction of large, scattered boulders within this uppermost channel section. These, along with pinned woody debris, would also encourage the formation of sorted spawning gravel deposits. Moreover, the opportunity exists to work with the operators of the reservoir complexes in order to generate spawning migrations by deliberate releases of water of the appropriate magnitude and timing. Heavy ongoing trapping of crayfish within the created gravel/boulder breeding zone in this uppermost reach would be essential to prevent crayfish predation of eggs.

Taken together, these actions would support a greatly increased production of juvenile fish for the high quality reaches noted in the River Restoration Centre report just downstream of Etherow works weir. It would provide both the conduits and motivation for adult fish to migrate between both sections of river – as well as generating high quality breeding habitat where egg predation by crayfish is low or absent (Fig. 22)

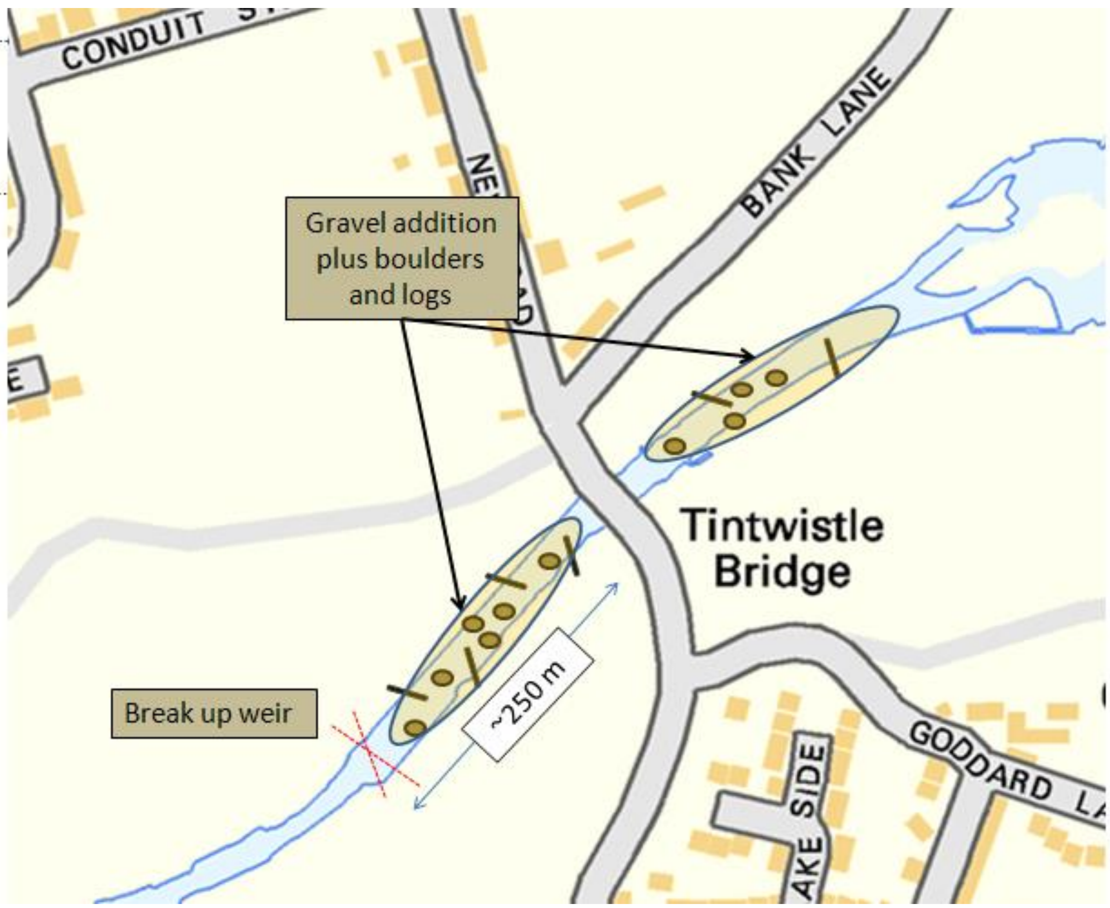


Figure 22: Habitat creation, velocity improvements (via weir removal) to be undertaken in concert with crayfish trapping, fish passage easement at Etherow Works and simulated spawning season spate flow dynamics via reservoir releases

All of the works proposed for the Etherow would need to be undertaken by a phased and partnership working approach. For the small-scale habitat enhancements within the channel (i.e. woody debris flow deflector and marginal brash installation), the WTT could potentially undertake these as part of their Practical Visit programme to train local stakeholders. The heavy plant work (i.e. wetland scrape creation, flood bund removal, gravel and boulder introductions) could be undertaken in partnership with E.A. Operations Delivery and/or local waterside businesses (such as Beeson's skip hire, adjacent to Bridge and Waterside Cotton mill weir site). Further discussion and allocation of project management roles, funding sources and sequential schedule of works should be undertaken following the issue of this report for consideration. Furthermore, these initial works should also be undertaken in parallel with a longer term programme to sequentially tackle barrier removal (where possible) and fish passage easement (where removal cannot be achieved) throughout the Etherow system.