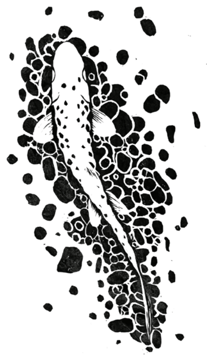
FLOODS, DROUGHT AND TROUT

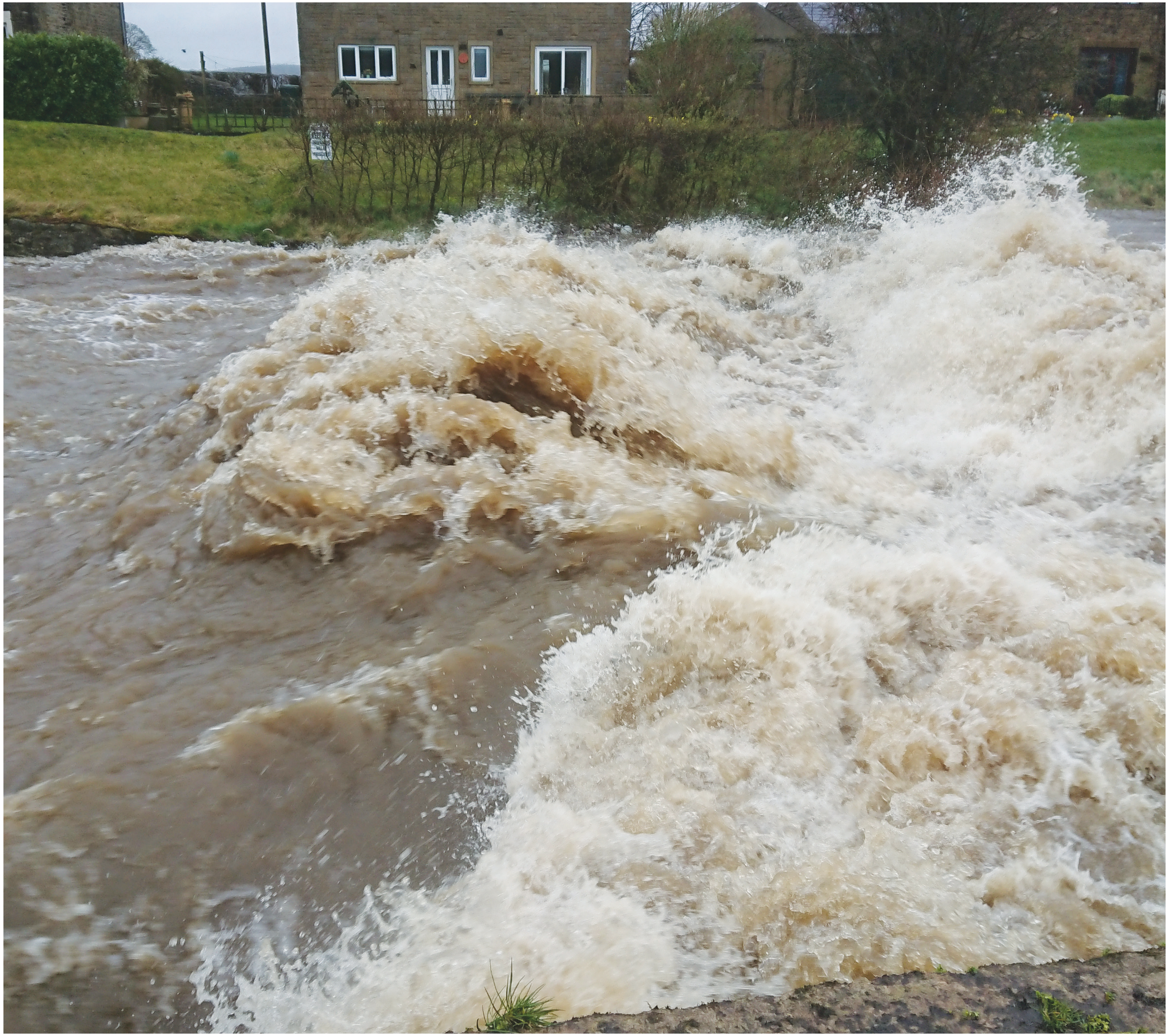
Jon Grey



At the end of the trout season, I generally take a month sorting tackle, flies and putting things away 'til spring. Then, after the first frosts knock back the bankside vegetation, I'm out again over winter 'chasing the ladies' - only, to misquote Benny Hill in *The Italian Job*, "I like 'em big". Personally, I also like 'em to bite back because for me, the only way is *Esox*. But pike or grayling, it matters not. Winter '22/23 as I write; I can count on one hand the hours spent in this pursuit. Trout season ended, and finally we got some much-needed rain. More rain, a quick hard frost when the rivers dropped to summer low again, and then rain, warm rain… *Ad libitum, ad infinitum, ad nauseam*.

Summer '22, the opposite extreme... thin water, bleached cobbles, the proverbial 'river on its bones'. Virtually nothing made it past the grass and into the Aire for months. Climate change, eh? The broad-brush picture for the UK predicted too long ago now was for milder, wetter winters and hotter, drier summers. And so it has come to pass - more flooding and more drought. But alongside those general trends were predictions of the less predictable, an increase in the frequency (and duration) of extreme events. What could such extremes of flow mean for trout and the wider ecology of our rivers?

Firstly though, it's important to take a step back and ►



remember that physical disturbances such as floods and droughts contribute to dynamism, causing a 'shake-up', by removing organisms, sculpting habitat, and/or creating access to resources for those species able to resist or recover from such events. On river walks, talks, and in Advisory Visit reports, I often state that physical diversity begets biological diversity. The underlying physical (geomorphological) structure of rivers determines the quantity and quality of habitat available, so changes to morphology from an extreme disturbance event are likely to affect river ecology beyond the direct effects of the event per se.

Ideas of disturbance relating to species richness can be traced back in ecological papers to the 1940s and were formalised in the 1970s as the *Intermediate Disturbance Hypothesis*. Essentially, if a river (in our case) remains relatively undisturbed, then species richness declines as competitive exclusion increases, ie that 'stale' state favours a handful of species which become dominant. In a river that is disturbed more frequently, the shake-ups or habitat 'resets' keep everything on its toes, as it were, and no one thing can dominate. However, as disturbance becomes even more frequent/extreme, species richness declines again as only a few can tolerate the conditions. The latter scenario is where we are headed.

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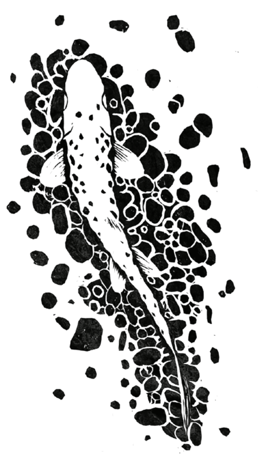
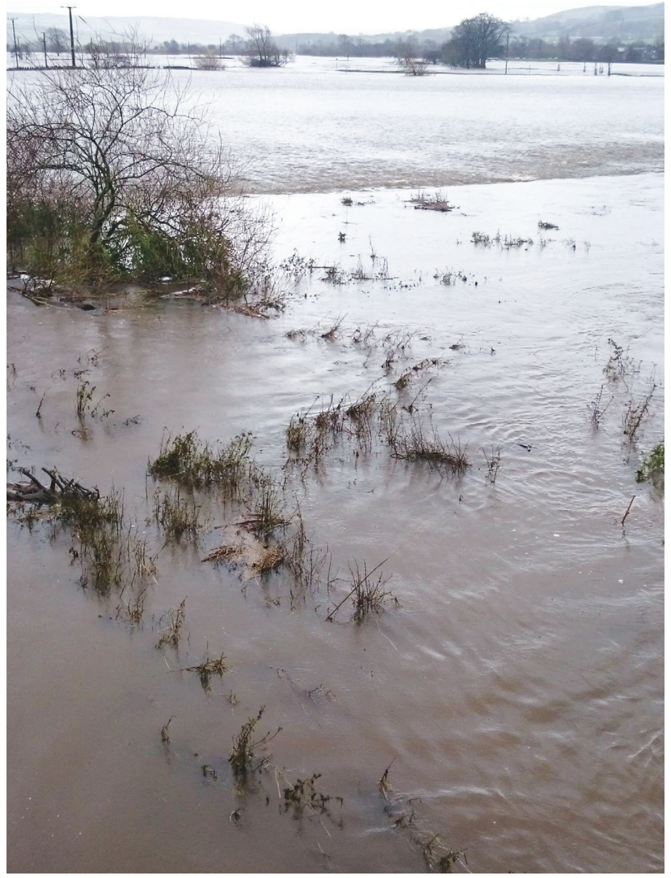


Ecologists know that both gradual (long-term trends such as warming) and extreme (intense event) weather changes bring about a plethora of complex ecological responses in rivers. Less clear is which is more likely to have a profound impact upon aquatic biodiversity or functioning: *trend* effects or *event* effects. Late in 2022, a team from Spanish, Portuguese and Chilean universities analysed 71 published studies of aquatic ecosystems: it was *event* effects associated with flow and temperature that had a disproportionate impact, for example on biodiversity by substantially reducing species richness, particularly of invertebrates *(Sabater et al, 2022)*. Of the two extreme events though, generally it was not floods but drought and specifically flow interruption that produced the largest effects. Hence, while we may stand on a river bank and despair at the raging torrent of water passing before our eyes, it is the seemingly innocuous low flows compounded by temperature that do the real damage.

That said, I tend to get more questions about floods, so let's start with too much flow. The temporal context is important as well as the magnitude and duration of the event, and the functionality of the channel (more on that later), as these will determine how organisms respond. Most folk associate (winter) floods with wash-out of gravel/redds/eggs/swim-up fry; summer floods tend to have less of an impact because fry/parr are much more capable swimmers by then. Extreme winter flooding can mobilise sediments to such an extent that virtually all of the annual egg production may be lost. However, the benefits of a lifecycle involving laying of eggs in winter when rivers are prone to flood must outweigh the costs at the wider population level. Mitigation measures include over-production of eggs, yielding a greater chance of at least some surviving extreme events. Lost production in one year effectively creates a cohort gap within a population and leaves resources (food/shelter) which can be exploited by the production of previous or subsequent years; less competition = faster and/or greater growth. Loss of one or two years of production across a five to eight year period would be barely detectable in a wider population – that intermediate disturbance idea. Loss of three or more years of production over the same time period, especially consecutively, would probably start to take a toll.

It's difficult to dissociate quantity of water from temperature when talking about climate change. One aspect of the increase in more extreme winter flooding is milder temperatures and less snow. Thirty or more years ago, winter temperatures were more stable and snow was precipitation effectively locked up on land, released by thawing gradually. In recent decades, typically we have rain falling upon (already) rain-saturated ground. Wild temperature swings mean that even if we do get heavy snowfall one day, it may quite literally thaw within the next and be lifting the river gauge in no time.

What about being washed downstream? Riverine fishes and invertebrates are adapted to flow, some better than others. High flow events rarely displace wild trout any great distance, but of course they will seek out more energy efficient lies. If a river is well connected to its floodplain, then trout may move out onto that inundated floodplain to take advantage of slacker flow (and feeding opportunities on soil invertebrates). However, they are unlikely to reside for long in shallow(er) waters and will generally return in good time as the level drops rather than be stranded. Unlike wild trout, stocked trout lack the local adaptations and/or real-life experience to deal with high flow events and generally 'go with the flow', dispersing downstream ►



in the hope of finding more favourable conditions.

Autumnal rains provide one cue for salmonid spawning migration, both seafaring and river 'resident'. Intense, flashy lifts and falls in river level present smaller (shorter) windows of opportunity for migration, resulting in a stuttering run and potentially leaving fish in limbo for periods (taking longer time, expending more energy, exposed to predation pressure etc). Unfortunately, those intense lifts can amplify the effect of many other anthropogenic stressors, for example by mobilising nutrients, sediment and toxic chemicals that have accumulated on fields or road surfaces. A plug of pollution surging through the system may cause an acute reaction in fish, a behavioural response to the chemical constituents rather than a physical barrier to movement, as well as a chronic reaction of the specific toxins or nutrients. We shouldn't overlook how such extreme events also may facilitate the dispersal and establishment of invasive non-native species.

And droughts? The ecological impacts of droughts on rivers again are determined by the temporal context and the extent to which they are dependent on surface run-off and/or ground water. Under extreme conditions, droughts cause reduced water-flows, reduced depth and width, flow cessation and loss of connectivity, and potentially complete desiccation (although water may continue to flow within the hyporheic zone, the substrate below the bed). Headwaters and tributaries tend to be more susceptible to drying than larger, mainstem rivers downstream. Typically, we think of droughts associated with hotter conditions and then it becomes more difficult to disentangle temperature effects from low flow effects, but droughts can occur overwinter too, as we have seen in February 2023, the driest in England for 30 years. Most questions I receive regarding droughts are actually temperature, rather than flow related.

Reduction in flow within a river can reduce the area or volume and quality/diversity of habitat available, prevent more extensive movement by fish, increase exposure to damaging ultraviolet light, heat stress or frost, predation etc, and may result in the isolation of larger individuals. Furthermore, substrate physical structure (eg grain size of sediment decreases; more fines) and chemical composition (eg pollutants/nutrients become more concentrated) change as flows slow and potentially dry out. On the Dales rivers near to me, extreme drought sandwiches the wetted channel between two slices of bleached boulders, completely separated from any shady overhanging banks.

There are many common messages from studies around the globe on the impacts of drought on salmonids. Extensive delays to spawning migrations due to fragmentation of the river causes unnecessary energy expenditure, shorter window of opportunity, increased risk of predation but also potentially exposure to diseases and parasites like *Saprolegnia* or lice that thrive under lower flow conditions. Spawning gravels may become filled and smothered with fines and biofilms, rendered unsuitable for redd excavation and egg incubation. Fry mortality increases, primarily associated with competition for less resource, be that spatial (ie a simpler or restricted habitat such as loss of stream margins offering less refuge from predation), or dietary (ie less food for hungry mouths). Obviously, for older fish, a reduction in volume or depth typically impacts upon the larger individuals earlier and where emigration is possible, fish simply leave to find more suitable habitat elsewhere.

Should we be rescuing 'stranded' fish, those in dwindling, isolated pools? The ecologist in me says we shouldn't, based upon survival of the fittest. We don't know whether the most drought-savvy fish have already left the building, and we could be inadvertently interfering with local adaptation by reintroducing unfit fish back into the population. What we should be doing is making the river as functional as possible, increasing the resilience of the ecology, and that will ultimately bring me back to my functionality point from earlier.

Just before that, for simplicity, I have discussed aspects of the two extremes of water quantity as separate issues, yet in the complex of ecological reality, that is rarely the case. Such things are generally interlinked by 'carry-over effects'. The number of fry produced may be substantially reduced by extreme winter flood events but, given a good spring and summer season, those fry should do better than average because of less competition for resources (as discussed above). Too often now though, we switch almost immediately to drought conditions (2022 a case in point), limiting access to resources and increasing the physiological challenge to survive and thrive for those few fry. A subsequent carry-over may then be that the fry challenged by drought conditions over the summer are ill-equipped (smaller, insufficient energy reserves) to deal with the rigours of spate flow come the winter. And so on, severely whittling down the number of trout that make it through to parr and adult stages.

Finally...functionality! Humankind has an inherent desire to reduce the immediate effects of flooding and drought on society, typically through engineering of river channels. This presents conflict where the impacts of extreme events are exacerbated by man-made modifications to the landscape and pressures on the environment.

Urban development and agriculture have reduced permeability of water into the ground (eg with tarmac or soil compaction by livestock), increasing conveyance off the land to streams and rivers rather than recharging aquifers. Excessive abstraction from aquifers reduces groundwater and flow in rivers. Land drainage and flood defences generally reduce the ability of rivers to cope with extreme events, concentrating flow and increasing peak flood level, and subsequently meaning that little water is retained under drought conditions. Historical and ongoing engineering works

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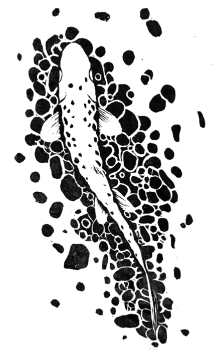

have tended to reduce habitat diversity both within individual rivers such as removing depth variation by dredging, armouring of banks, or regulating flows, and between rivers such as straightening of channels and standardising them into trapezoidal cross-sectional profile. By doing so, this has constrained natural processes and connections to floodplains that provide rivers with the resilience to withstand extreme events without lasting damage.

Rather than working with natural processes, human interventions have tended to exacerbate the undesirable ecological consequences of such events. What we at WTT always advocate is retaining as much (or returning to as much) natural functionality as possible for the widest possible ecological and societal benefits. Almost counterintuitively, it may take extreme flood events to overwhelm current human constraints and infrastructure to increase habitat complexity and floodplain area, thereby benefitting riverine and riparian biota in the longer term. ❑

Jonathan Grey divides his time between the academic world as Professor in Practice at Lancaster University and delivering practical advice and projects as WTT Research and Conservation Officer based in Yorkshire.