The health of the River Leen

A field investigation of habitat & water quality in the River Leen

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Introduction

Urban rivers like the River Leen have been heavily managed by humans to make space for development and to control flooding. They often have poor habitat quality, as the channel has been straightened and cleared of vegetation and structure. Many urban rivers also have problems with water quality as towns and cities are potential sources of numerous pollutants. For example, road drains, treated and untreated wastewater discharges, misconnected pipes, and industry can all be sources of harmful substances.

Rivers with uniform channel shape and homogenous flow and sediment conditions are less resilient to floods, pollution, and climate change, and are limited in the diversity of organisms they can support. High levels of pollution affect the survival of both aquatic and terrestrial biota. Rivers in a poor state of health provide fewer benefits to local people (through recreation opportunities like fishing, wildlife watching, or walking) and can affect human health and societal development. Water and habitat quality are therefore important measures of river ecosystem health. By understanding the current condition of a river, we can better manage it to improve rivers for people and wildlife.

To this end, this report documents the findings of an investigation into the habitat and water quality of the River Leen through the city of Nottingham. We monitored ten sites along the River Leen over a few weeks in April and May 2021 (Figure 1). Comparing the results over time, space, and with previous monitoring data from the Environment Agency (EA, 2021a) meant we could evaluate the current health of the river and what could be done to improve it.

Water Framework Directive

The health of rivers in England is assessed by the Environment Agency (EA) according to standards outlined by the Water Framework Directive (WFD: 2000/60/EC) Directions (2015). In accordance with the WFD, classifications of waterbodies are typically reviewed at least every six years and are split into four categories: high, good, moderate, and poor. In most cases, WFD status is classified according to the lowest classed biological, physico-chemical or specific pollutant quality element. The aim for the River Leen is to achieve good status (or potential for the lower Leen) by 2027, defined as there being only a slight difference from the biological community that would be expected if anthropogenic impact was minimal.

The River Leen is split into two waterbodies which are separately assessed for WFD: the Leen from source to Day Brook (at Basford), and the Leen from Day Brook to the River Trent (Figure 1). The second of these is designated heavily modified, because development has substantially and irreversibly changed the waterbody characteristics. As such, it is required to reach good ecological potential rather than good status.

Both waterbodies were classed as moderate status in 2019 (the most recent assessment; Table 1). The upstream waterbody is affected by point source sewage discharge which limits macrophytes and phytobenthos, but fish and invertebrate status in this waterbody were classified as high and good respectively. The downstream waterbody which flows through the most urbanised area is affected by pollution from sewage and transport drainage, as well as by physical modification. As a result, the status for fish is poor, despite invertebrate status being good. The physico-chemical quality status of the river is high or good, but both waterbodies fail for some priority hazardous substances.

Table 1: Water Framework Directive classifications for the River Leen in 2019 from Environment Agency (2019 a, b).

Classification item	Leen from source to Day Brook	Leen from Day Brook to Trent
Hydromorphological designation	None	Heavily modified
Overall waterbody	Moderate	Moderate
Macrophytes and phytobenthos	Moderate	Not assessed
Fish	High	Poor
Invertebrates	Good	Good
Hydromorphology	Supports good	Supports good
Physico-chemical quality	High	Good
Specific pollutants	High	High
Priority substances	Good	Good
Priority hazardous substances	Fail (PBDE, PFOS, Mercury)	Fail (PBDE, PFOS, Mercury)
Reasons for not achieving good status	• Point source sewage discharge	• Diffuse pollution from transport drainage • Point source sewage discharge • Physical modification

Our monitoring approach

The WFD assessment of the River Leen is based on regular monitoring at a small number of sites along the river. For this report, we have sampled water quality and invertebrates, and assessed habitat quality at those sites monitored by the EA within the city boundary, as well as at a number of other sites (Figure 1) in order to increase the spatial representation of the river health through Nottingham. We sampled at ten sites (numbered going downstream), split between the two waterbodies, during April and May 2021. Our results are presented alongside data from the EA (EA, 2021a) to explore the ecosystem health of the River Leen.

This report focuses on three aspects of river ecosystem health:

1. **Habitat quality:** We used the River Habitat Survey (RHS; EA, 2003) to assess the habitat quality and extent of modification of each sampling site in a standardised way.

2. **Water quality:** We directly measured water quality and took samples for laboratory analysis on four sampling dates. Measurements include pH, electrical conductivity, dissolved oxygen, and specific nutrients (ammonia and soluble reactive phosphate:

SRP). We compared these measurements with standards to understand different aspects of the water quality.

3. **Invertebrates:** We took a kick sample (Murray-Bligh, 1999) of invertebrates living in the riverbed on one of our sampling dates. This method disturbs the riverbed (by gently kicking the substrate) and then collects the dislodged invertebrates in a net. The invertebrates were then identified in the laboratory.

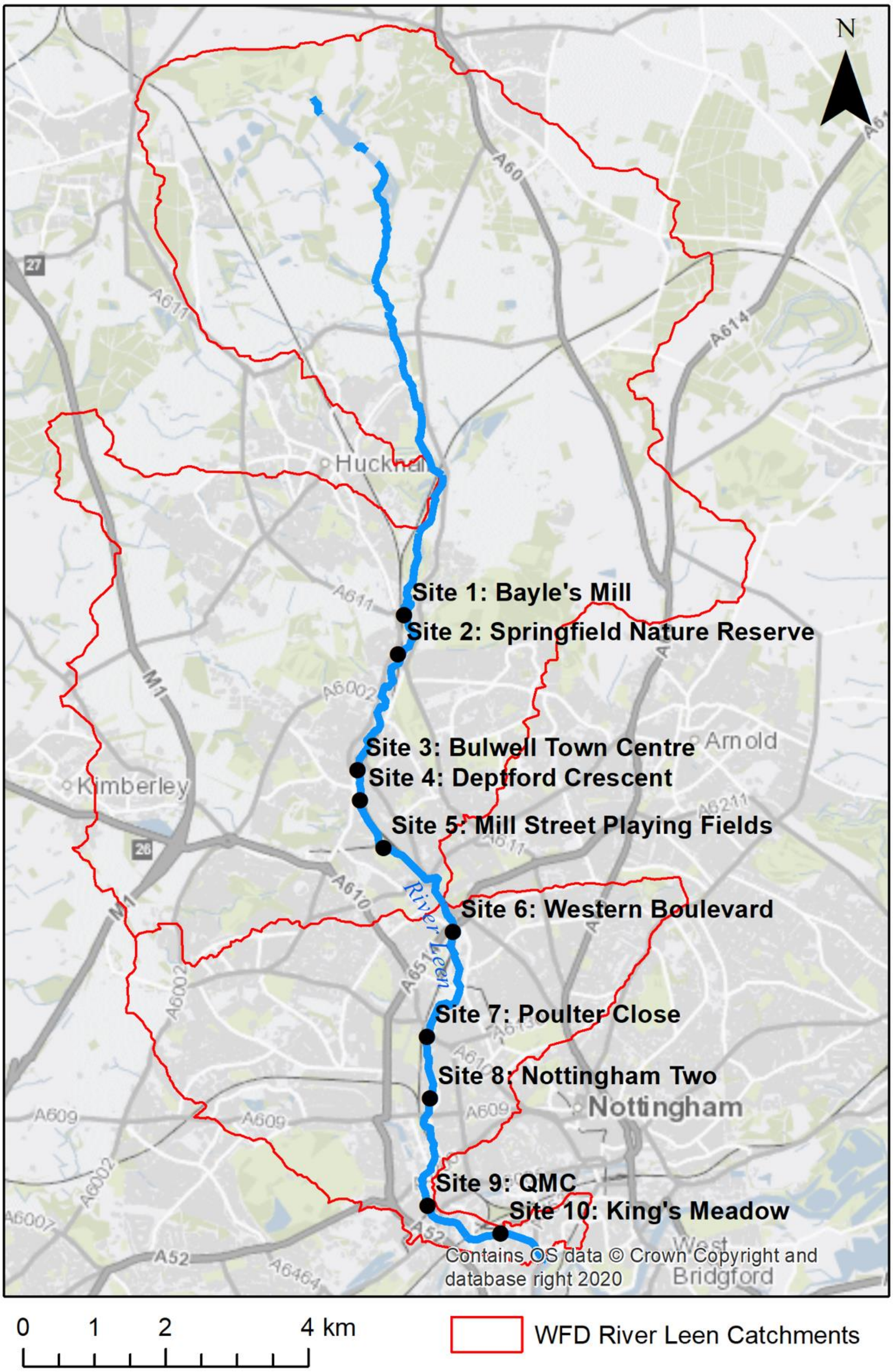


Figure 1: Sites monitored on the River Leen for this study. The red lines delineate the two Water Framework Directive (2000/60/EC) catchment areas used to classify the ecological status of the river: the upper catchment from source to Day Brook, and the lower catchment from Day Brook to the River Trent. Data from EA (2021b) and OS Open Rivers (2021).

Results

Habitat quality

To assess the habitat quality of the sampling sites we used the River Habitat Survey (RHS), which is a standardised way to score river habitat characteristics. The RHS method calculates two indices: habitat quality assessment and habitat modification score (results shown in Figure 2). Habitat quality is assessed by examining the occurrence and diversity of valuable habitat features and comparing this to other similar rivers. The habitat modification score is determined by assessing the extent, potential impact, and persistence of river engineering structures, such as culverts, realignment, and bed/bank protection, on the river (Walker, 2005).

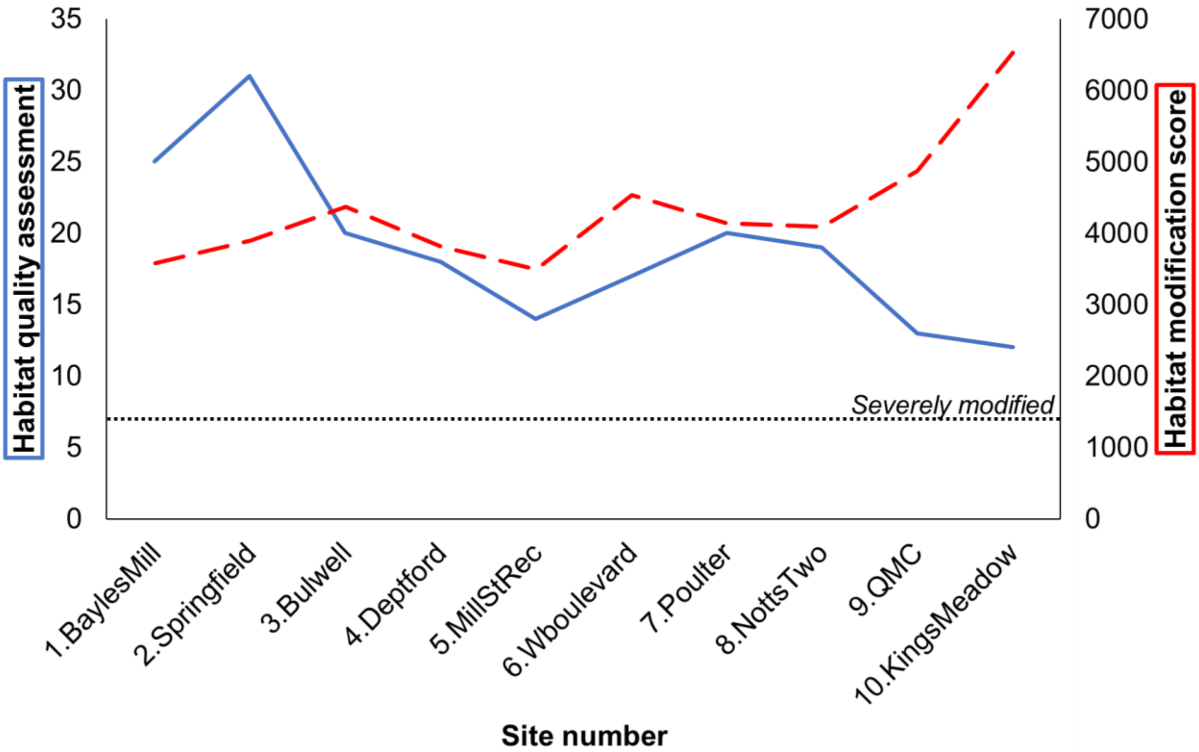


Figure 2: The habitat quality assessment (blue solid) and habitat modification score (red dashes) for the ten sites surveyed. The black dotted line shows the score for habitat modification above which sites are classed as 'severely modified'.

We found that all the sites we surveyed were classed as severely modified (> 1400 habitat modification score) and that the extent of habitat modification increased with distance downstream. Correspondingly, the habitat quality of sites decreased going downstream. This suggests that the extent of modification limits habitat quality by reducing the diversity of habitat. The most modified site was at King's Meadow, where the river has been channelised and over-deepened, the bed and banks are reinforced with concrete, and the river is heavily embanked (Figure 3). This means that the river has limited diversity in flow and sediment conditions, negligible riparian vegetation, and few natural habitat features (such as backwaters, wood pieces, bars, or berms), all of which are valuable habitats for a variety of aquatic and terrestrial biota. It has been found that the physical modification of the lower waterbody (Leen from Day Brook to Trent) is one of the elements limiting the WFD status for fish (EA, 2019b). Physical modification restricts the availability of habitat (e.g. suitable spawning conditions or low flow areas where fish can shelter from floods) and prevents the movement of fish along the river (Baras and Lucas, 2001; Dias *et al*., 2017). Attempts have been made to rectify fish habitat loss through restoration (e.g. at Queens Medical Centre, recent works to repair erosion and stabilise flood defences have also added cobbles to the riverbed for fish habitat) but many reaches of the Leen remain artificial and heavily modified.

Figure 3: Photo of the sampling site at King's Meadow (site 10). This site is the most heavily modified of those sampled; the river is straightened and over-deep, the bed and banks are reinforced with concrete, and there are several outfalls and bridges. This means overall habitat diversity is limited which restricts the ecological quality of the site.

Water quality

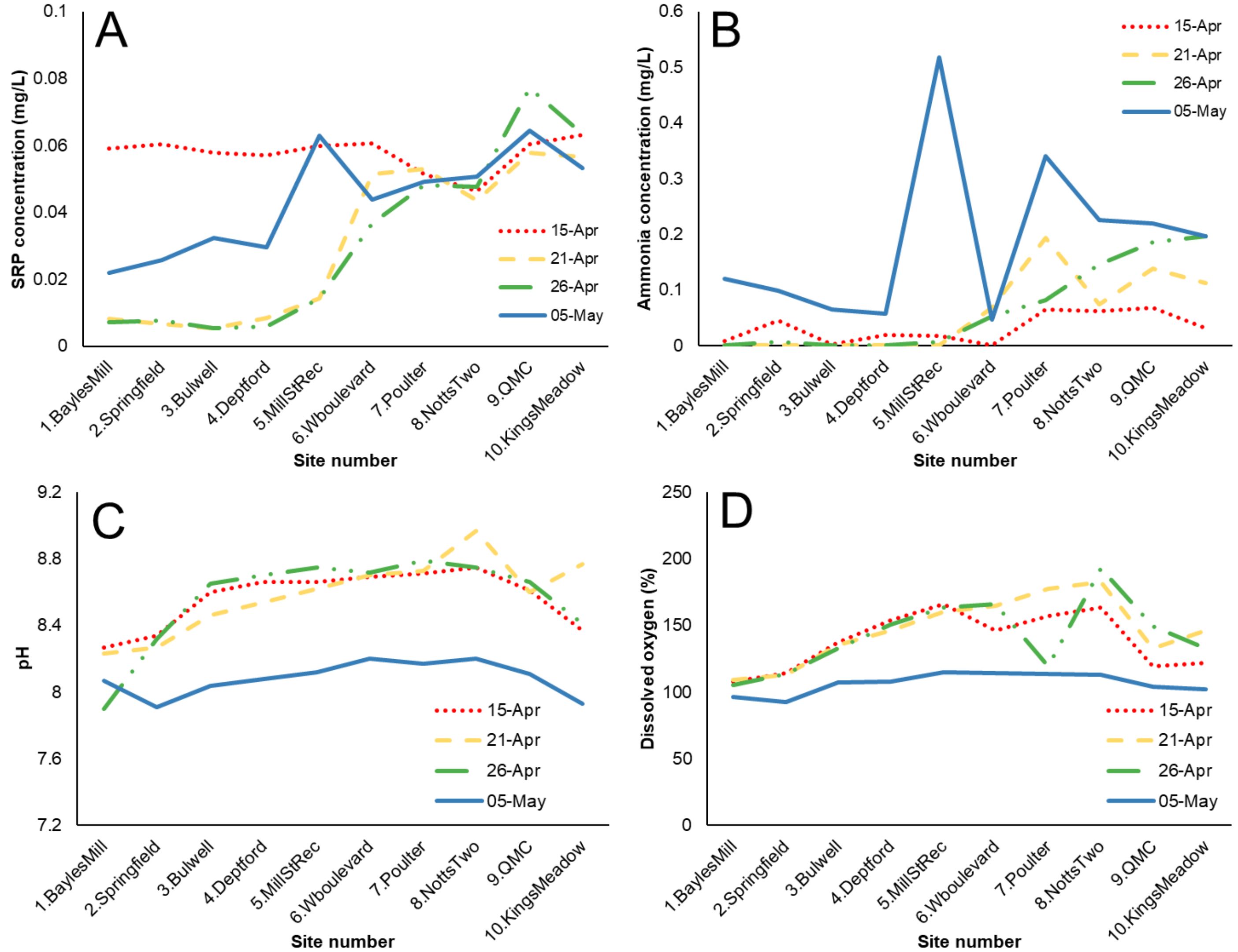
Since 2013, physico-chemical quality elements for the River Leen have, overall, been consistently high for the upper catchment from source to Day Brook (EA, 2019a) and consistently good for the heavily modified lower catchment from Day Brook to the River Trent (EA, 2019b). The decline in status downstream is as would be expected due to the increased urban development towards Nottingham city centre. The data collected during this study supports this assertion (Figure 4), indicating that in terms of physico-chemical quality, the River Leen's ecological status has remained steady in recent years across its two catchments. Dissolved oxygen, pH, and water temperature for both catchments have consistently been classified as high since 2013.

Some key physico-chemical quality elements considered by the WFD are nutrients including ammonia and SRP, which is the biologically available form of phosphate. Inputs of nutrients is one of the most widespread forms of pollution in the UK, and it can be damaging to the ecology of rivers (Department for Environment Food & Rural Affairs: Defra, 2014). Increased

SRP concentrations in rivers can lead to accelerated growth of algae and plants which can, in turn, impact oxygen levels and river habitat characteristics, leading to significantly altered community structures (Defra, 2014). High SRP concentrations, a major source of which is wastewater treatment works (Daldorph *et al.*, 2015), are responsible for a large proportion of waterbodies not achieving good ecological status. Ammonia, high concentrations of which are also damaging for fish and invertebrates, may be discharged into rivers intermittently, usually from combined sewage overflows and storm tanks following rainfall (Defra, 2014).

Concentrations of SRP in our sampling sites exhibit a clear difference between the upper and lower Leen catchments (Figure 4a). For two of our sampling dates, a clear increase in SRP concentration downstream of the Day Brook tributary can be seen, suggesting that Day Brook (also a heavily urbanised waterbody) is probably a source of SRP to the River Leen. The Day Brook was classified as poor for ammonia and moderate for phosphate in its most recent assessment (EA, 2019c). SRP concentrations were much more variable in samples from the upstream waterbody, despite the short sampling timeframe of a few weeks. This suggests inconsistent sources of SRP in the upper reaches of the Leen, whereas SRP input to the Leen closer to the city centre is more steady and likely to be from point sources such as wastewater treatment works (Defra, 2014). Ammonia concentrations also increase with distance downstream, although the variation between sampling dates is again high at each site (Figure 4b). For example, field data collection on our final sampling date (5th May 2021) followed a few days of heavy rainfall, and the marked increase in ammonia found only at Mill Street playing fields (site 5), is likely to be a result of a point source outfall triggered by the rain. This rainfall also explains the decreased pH, dissolved oxygen, and (less distinctly) electrical conductivity found on that date (Figure 4c, d, e), as these measures were probably diluted by the increased volume of water in the river.

Assessment of the WFD status of individual sites (which can only be assessed for sites with long-term data from the EA, 2021a) shows that ammonia concentrations have remained consistently low since 2013, with all four EA sites being classed as high status. Figure 6 shows these ammonia concentrations alongside our 2021 data, which suggests that ammonia concentrations are still falling in the Leen. SRP concentrations have also decreased over the past decade (Figure 5). Bayle’s Mill, Bulwell town centre, and Poulter Close (sites 1, 3, and 7 respectively) have all improved SRP status from good to high, and King’s Meadow (site 10) has improved from moderate to good. Given that SRP concentrations have such an impact on overall classification (Daldorph *et al.*, 2015), this is a positive outcome and suggests that the water quality in the River Leen is improving over time.



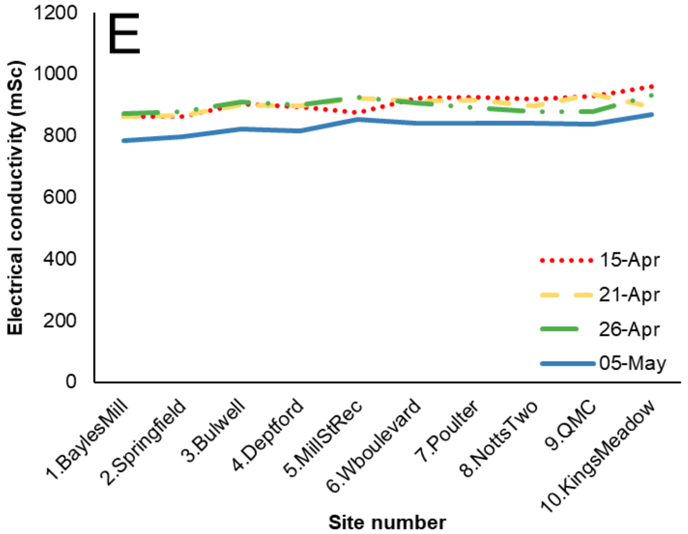


Figure 4: Physico-chemical data for our ten sampling sites on the River Leen: (a) soluble reactive phosphorus; (b) ammonia;(c) pH; (d) dissolved oxygen; (e) electrical conductivity.

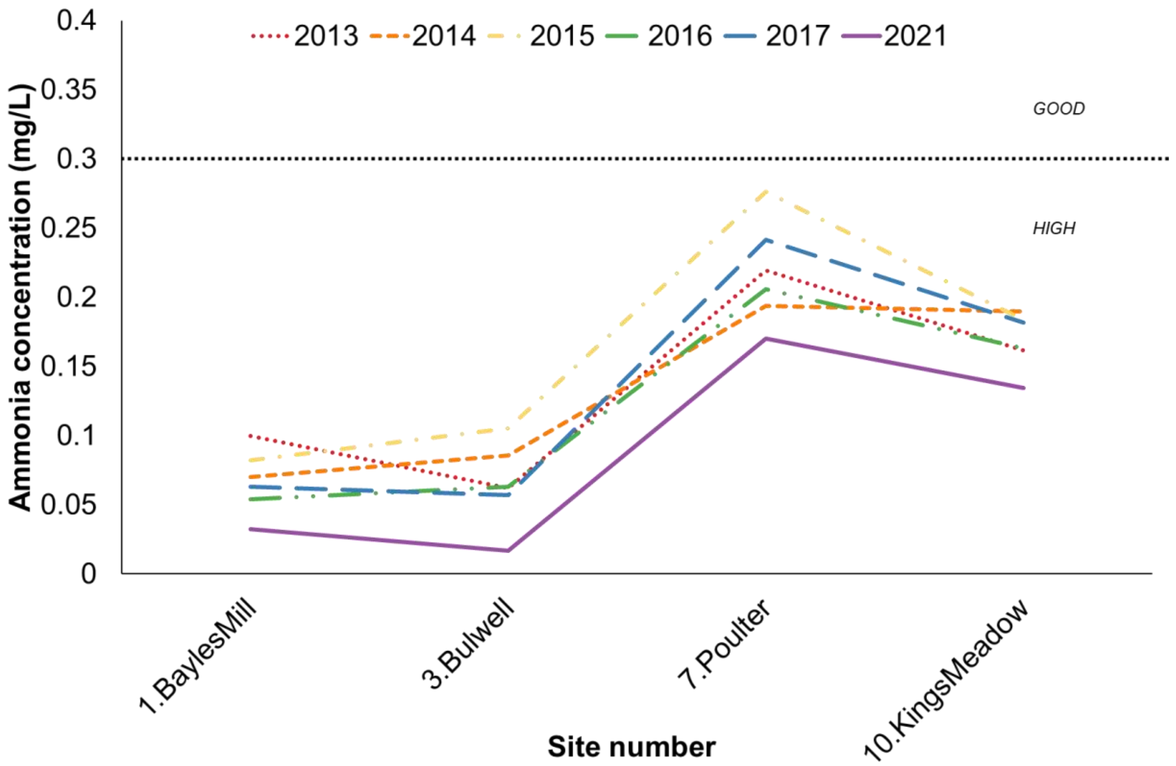


Figure 6: Ammonia concentrations for four sites on the River Leen for sample years 2013 to 2021. 2013-2017 data collected by the EA (2021a) and 2021 data collected during this study. The threshold value between good and high WFD classification standards is indicated by the black dotted line.

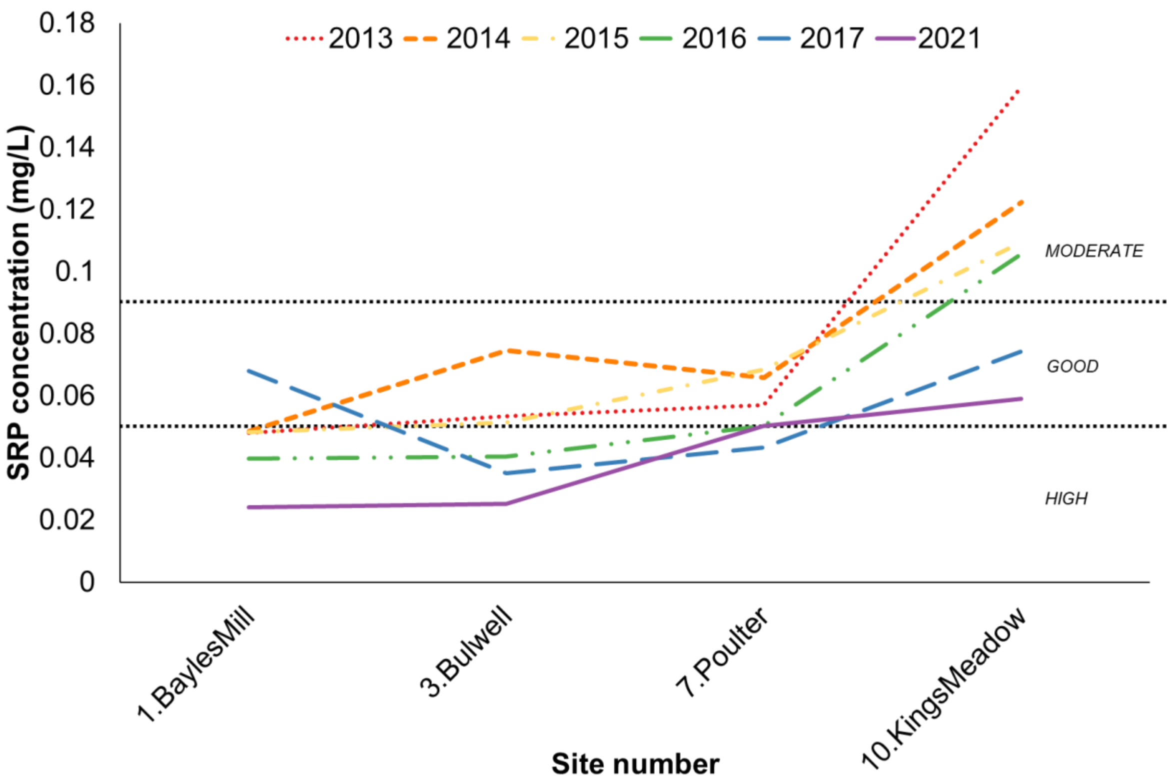


Figure 5: Soluble reactive phosphorus (SRP) concentrations for four sites on the River Leen for sample years 2013 to 2021. 2013-2017 data collected by the EA (2021a) and 2021 data collected during this study. The approximate threshold values between moderate and good, and good and high WFD classification standards are indicated by the black dotted lines.

Invertebrates

Aquatic invertebrates (including the nymphs/larvae of flies, mayflies, caddisflies, and damselflies, as well as crustaceans, snails, worms, and beetles) are common and useful indicators of the biological condition of rivers. In general, healthy rivers support a high diversity and number of invertebrates, whereas unhealthy rivers will only contain a few species. Inspecting the specific species present in a river can tell us about the river's health because each species prefers different habitat conditions and can tolerate different levels of pollution. We sampled invertebrates at nine of the ten sampling sites (it was unfortunately impossible to sample at Bayle's Mill because of the river depth and deep silt). These results were compared to eight years of EA data (since 2013) at QMC and Poulter Close (sites 9 and 7 in our study respectively) and at Ravensmead and Bayle's Mill (sites located upstream of the city).

We found 48 taxa (from 36 families) across all sites, making up a total of 6866 individuals. The most abundant taxa were the snails: *Potamopyrgus antipodarum* and Sphaeriidae, and fly larvae: Chironomidae and Simuliidae, which are fairly common taxa. We also found three species of mayfly, 15 species of caddisfly, 11 snails (bivalves and gastropods), 7 fly larvae species, 3 beetles, 4 leeches, and 2 crustaceans. Only one species (*P. antipodarum*) was non-native.

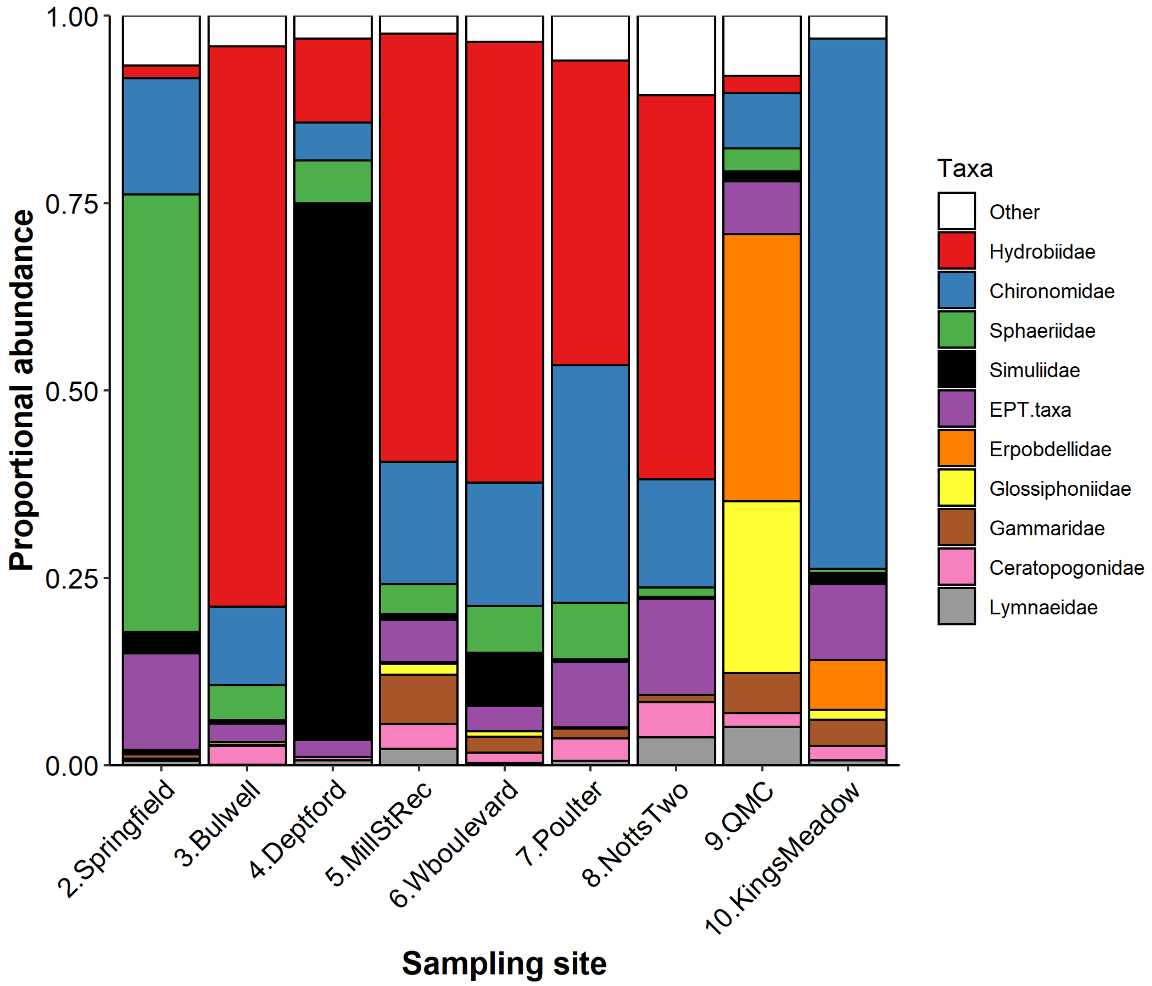


Figure 7: The proportional abundance of the ten most common taxa found across all sampling sites, with EPT taxa shown together. Other uncommon taxa that were found are shown as a group in white, indicating that the ten most common taxa made up 89 to 98% of the invertebrates in each sample.

Figure 7 shows the proportional abundance of the ten most common families. Springfield Nature Reserve, Deptford Crescent, QMC and King's Meadow sites had quite different communities to the other samples, manifesting as a lower proportional abundance of Hydrobiidae (a type of snail: *P. antipodarum*) that dominated in other sites. Instead, Springfield Nature Reserve had high proportional abundance of Sphaeriidae (pea mussels), and Deptford Crescent of Simuliidae (blackfly larvae); both taxa which can occur in very high numbers where conditions are suitable for them (Maitland and Penney, 1967). QMC samples had much higher proportions of Erpobdellidae and Glossiphoniidae (leeches), which tend to be found in higher numbers where organic pollution levels are high (Hawkes and Davies, 1971). Similarly, the much higher proportional abundance of the pollution-tolerant Chironomidae (non-biting midge larvae) at King's Meadow suggests that water quality at these two sites at the downstream limit of the River Leen is poorer than that at upstream sites. This agrees with the finding that water quality decreases downstream. However, some differences in the community composition of invertebrates with distance downstream are to be expected as river characteristics typically change longitudinally, such as an increase in the discharge (volume of water), fining of sediment, and decrease in slope.

Ephemeroptera, Trichoptera, and Plecoptera (EPT taxa, shown in purple on Figure 7) were grouped for this analysis. These are mayfly, caddisfly, and stonefly taxa, and are generally considered to be indicators of good water quality. The moderate proportions of EPT taxa at QMC and King's Meadow suggests that any water quality problems at these sites are not so severe as to preclude these taxa. The low proportions of EPT at Bulwell town centre and Deptford Crescent are due to exceptionally high abundances of Hydrobiidae and Simuliidae respectively, rather than a reduction in EPT taxa numbers.

Figure 8 shows the family richness for the samples collected in this study, alongside the mean (± the standard error) recorded by the EA. Family richness is a measure of biodiversity, calculated as a count of the number of invertebrate families present in a sample. Our samples from the River Leen show that Springfield nature reserve, Western Boulevard and Poulter Close sites supported the greatest number of families; approximately three additional families were recorded at these sites compared to the others sampled.

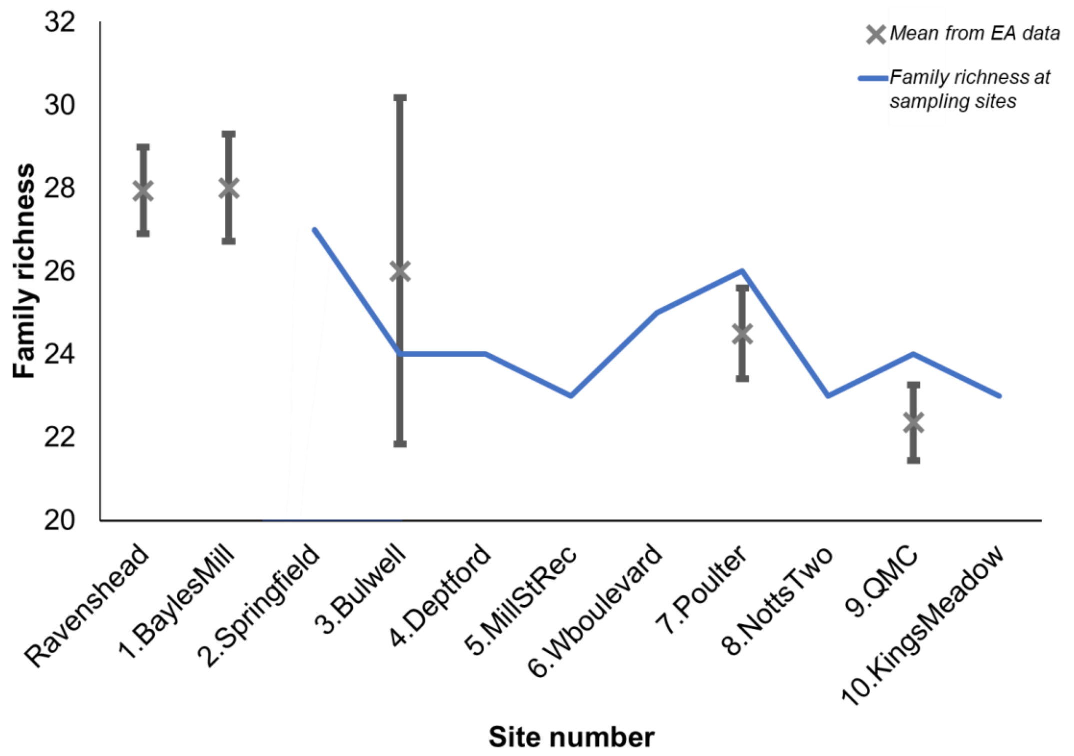


Figure 8: The family richness (number of families) of invertebrate sampling sites (blue line) and mean family richness (± standard error) for EA samples taken since 2013.

Although, our data found similar family richness to that recorded by the EA at the three EA sites we measured (Bulwell town centre, Poulter Close and QMC), the EA recorded higher diversity (mean: 28 families) at Ravenshead and Bayle's Mill (Figure 8). This is similar to what we found at Springfield nature reserve, suggesting that the sites upstream of Bulwell have better conditions for invertebrate diversity. This might reflect the decrease in habitat quality with distance downstream that we found in Figure 2. However, the differences are not large and there is no systematic change in diversity going downstream suggesting invertebrate diversity is not greatly affected by the reduction in habitat diversity or increase in nutrient pollution downstream.

As well as the diversity of invertebrates in a sample, the WFD assessment of invertebrates is based on the WHPT (Walley, Hawkes Paisley and Trigg) average score per taxa. This is an index that assesses the invertebrate communities in rivers in relation to environmental degradation, including organic pollution (WFD-UKTAG, 2021). Different taxa have distinctive sensitivities to environmental conditions, so that by looking at the presence and abundance of each taxa we can determine the condition of the river. The higher the score, the better the river status is for invertebrates. Figure 9 shows our results alongside the EA data. Most of the sites have a similar average score per taxa of between 4.8 and 5.2, which is similar to (or slightly better) than that found by the EA. The exception to this is the QMC site which scored only 4.1, reflecting the high abundance of leech taxa we only found at this site.

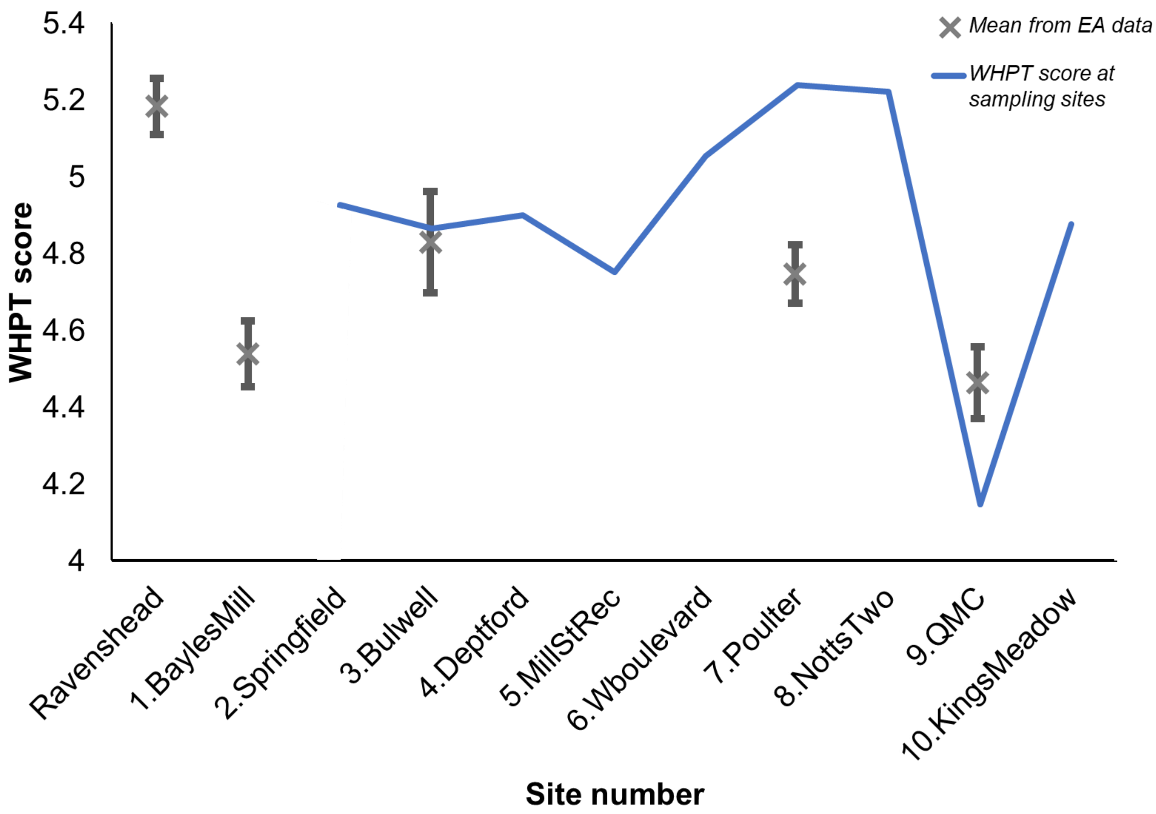


Figure 9: The WHPT average score per taxa of invertebrate sampling sites (blue dots) and the standard error around the mean average score per taxa for EA samples taken since 2013.

To calculate the WFD status, the diversity and WHPT scores together are compared to what would be expected for the river (based on its background environmental characteristics). Because we have only sampled during one season (spring) it would not be appropriate to calculate the WFD status based on our dataset alone. However, our results are sufficiently comparable to the EA data to suggest that the good status for invertebrates is applicable to all sites except perhaps at QMC, though more sampling would be needed to confirm this.

Conclusions

Our measurements show broadly similar results to the EA data, indicating that water quality and invertebrate communities in the River Leen are generally good. Some metrics are slightly worsened towards the downstream end of the catchment (e.g. SRP and ammonia), but long-term trends show that water quality has been improving over time.

Habitat quality, particularly in the downstream waterbody, is relatively poor, which is probably related to the high levels of channel modification. There is a possibility of future restoration of habitat to try and improve this, but this is challenging in the River Leen where space next to the channel is so restricted.

The sampling for this report was limited to only one month. Although by comparing with past monitoring data from the EA we can discuss the overall condition of the river, ideally sampling should be conducted over a whole year to truly understand the condition of the river. Taking measurements at a greater spatial resolution than the EA has, however, given insight into some local variability between sites. For example, we recorded a peak in ammonia concentrations at Mill Street playing fields, and high abundance of Glossiphoniidae and Erpobdellidae leeches at QMC suggests there may be a problem with organic pollution at this site. We also found variation in water quality between sampling dates (e.g. on our last sampling day which occurred after heavy rainfall). This indicates that although the overall water quality and invertebrates throughout the River Leen are at good or high status, there is the possibility of isolated pollution events.

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